JULY - AUGUST 1955

R/E

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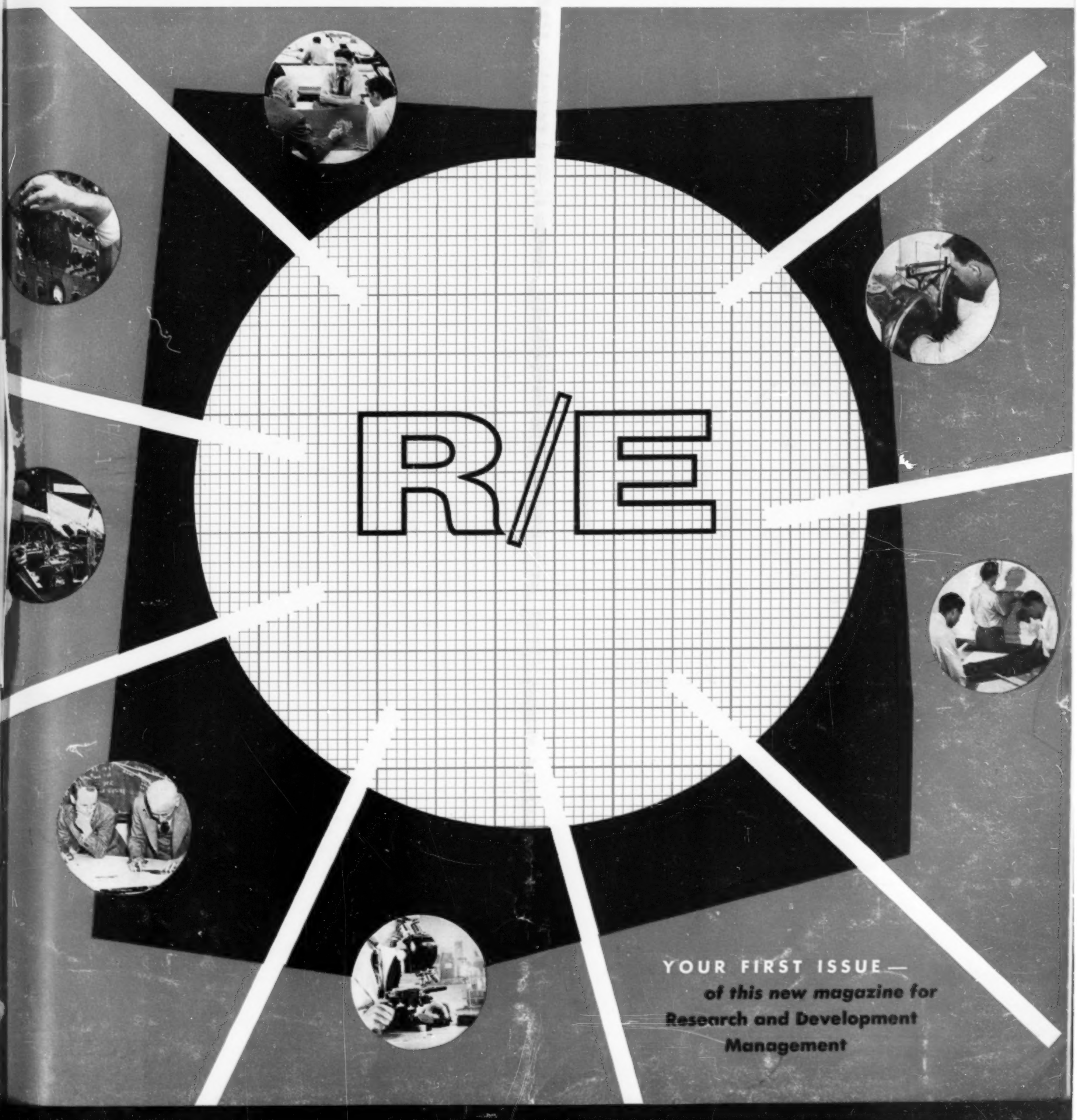
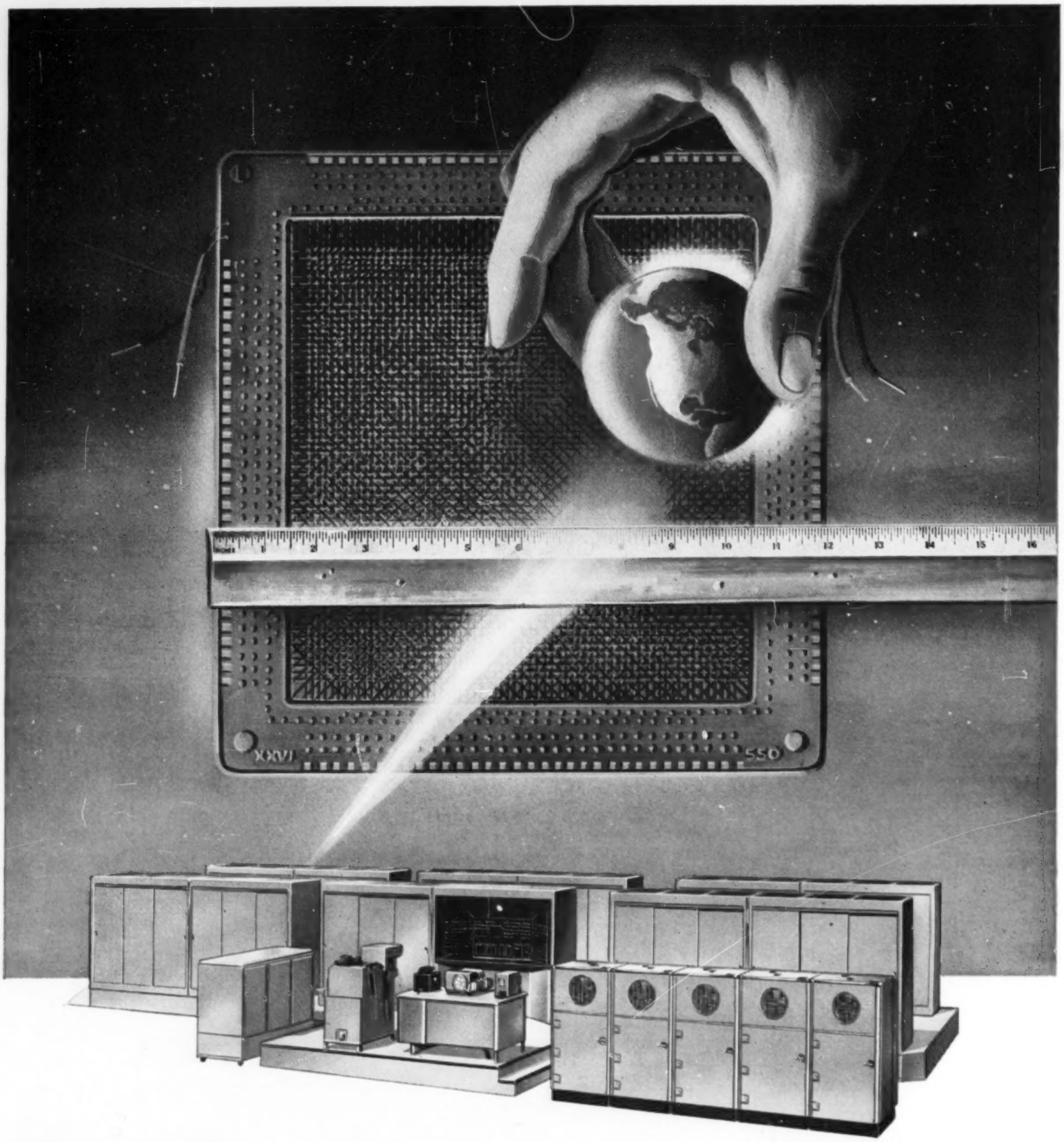
RESEARCH & ENGINEERING

Applied to Industrial Products and Processes





What's New in Mnemonics?

The Univac Scientific Computing System

The news is that the magnetic-core memory has emerged from the computer laboratory and has been in customer use for approximately a year, passing all tests with flying colors. This new development has been pioneered by Remington Rand with the Univac Scientific—the first installation of a commercially available computer that successfully uses magnetic-core storage.

Mnemonics, says Webster, is "the art of improving the efficiency of the memory." And, as far as electronic computers are concerned, Remington Rand has clearly established its leadership in this art.

Illustrated above is a single plane of core storage, each of which holds 4,096 binary bits of information. Planes are wafer thin, and a stack capable of "remembering" 147,456 bits would measure only 13 inches in depth. The speed, economy, and reliability of this magnetic-core memory are now available in the new Univac Scientific Models 1103A and 1103B.

For the latest information about the Remington Rand magnetic-core memories or about the Univac Scientific, write, on your business letterhead, to . . .

Electronic Computer Department, Room 1768

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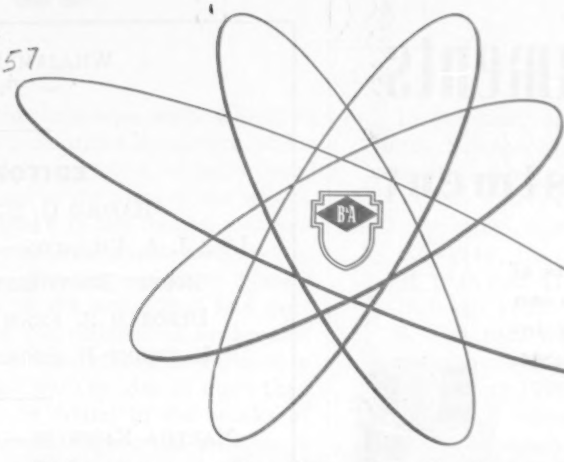

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Prospectus

When Galileo constructed the telescope with which he discovered the moons of Jupiter, he upset a segment of his colleagues who were enmeshed in a system of logic based on numbers. The planets belonged to the aura of the sevens. Among others were seven openings in the human and animal head; seven basic metals; and the ancients had divided the week into seven days. The discovery of more planets which would upset the balance of the seven that had been known for centuries threatened the collapse of an area of philosophy based on "sevens". Some authorities refused to put an eye to the telescope of Galileo. The idea of more than seven planets was nowhere to be found in the works of Aristotle; if more did in fact exist, they could only be in this monstrous instrument or indeed in the eyeball of its equally monstrous maker.

Today, as publishers, we cannot send forth this new magazine without some interpretation of what we have observed through our telescope. For our place among the planets is also related in some extent to numbers: the number of magazines now crossing your desk, and the amount of reading time saved by concentrating in one magazine more material pointed to your particular fields of business interest. So, we set forth our observations.

Those who study human relationships must of necessity analyze human activities and constituent forces that are continually at play as man strives to satisfy the needs of his existence. In the past certain types of human activities dominated to such an extent that the chroniclers of history did not have too difficult a time agreeing on labels with which they could handily refer to spans of years or centuries. Thus we have the Dark Ages, the Middle Ages, the Renaissance; and more recently, the Industrial Revolution. As far as we know, the Industrial Revolution with its beginnings in the 18th century is still running its course. But future historians who chronicle the times in which we now live may put the end of this era somewhere around the beginning of World War II.

Shortly after Hiroshima, "The Atomic Age" was a likely replacement for the "Industrial Revolution". But as powerful a force as nuclear energy is, it is still subordinate to the force that produced it: *Research.*

We believe we are on the threshold of a new age, the *Age of Research.* Until contemporary times, research was undertaken spasmodically and frugally by men who were curious about effects and forces that created them. Only in their dreams of Utopia did they approximate the research world of today. In his *New Atlantis,* Francis Bacon wrote of an English ship on a then bold voyage to the uncharted South Seas. The men came upon a Utopian island realm whose chief product was not bread-fruit and grass skirts, but a great establishment devoted to scientific research! Today, the dream has become reality.

In February of 1954, Dr. Raymond H. Ewell of the National Science Foundation published the following significant statistics:

1. The half-way point in research and development expenditures from 1776 through 1953 was approximately mid-1948; i.e., $16 billion were spent up to the middle of 1948 and $16 billion have been spent since mid-1948 through 1953.
2. The 1953 annual research and development expenditures were approximately equal to cumulative expenditures from 1776 up to January 1, 1940.

Industrial research is now advancing at a rate which can only be described as explosive. Current estimates indicate that in 1965 the annual dollar volume of research may reach the seven billion mark. American industry, stimulated with the achievements of research during 1940-1945, now considers research a normal and necessary part of its survival and growth. Financial experts measure the extent to which a company will survive and grow by the size of its R/D budget and the productivity of its R/D brains.

To direct the expenditures of time and dollars, top management has created a new executive group from the ranks of their technically trained men: division and department managers of research, design and development.

The editorial objective of R/E is to serve you, the new executive group, the managers of this vast research and development effort. Among your responsibilities are two basic ones: (1) to manage your section so that it functions smoothly and creatively and (2) to keep abreast of basic technological advances in all fields of industrial science so that relevant developments can be quickly inserted into your own programs. These two responsibilities will form the basic editorial content of R/E. Your additional needs—as we continuously research them—will form the content of current and future departments.

This first issue is dated July-August. Beginning with September, R/E will be published monthly. The concept of R/E represents eight years of research and consuitation with hundreds of engineering managers. We hope that now you, too, will write us frankly and constructively. We are not affiliated with any other publishing organization or with any of the technical societies; our goal is to be an impartial channel of communication between you and your colleagues in practical industrial and government research.

The approach to research that you are familiar with in your work will be similarly applied as editorial content originates in our pages. In this sense, our issues will be subjected to severe analysis; but, as in any controlled research program, all significant reactions must be interpreted and integrated. Candidly, you—the catalysts of R/E's research program—can accelerate the manner in which we uncover your needs and meet them.

Harold G. Buchbinder — **EDITOR**

Wm. H. Relyea, Jr. — **PUBLISHER**

R/E

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VOLUME 1, NUMBER 1

THE MAGAZINE OF RESEARCH AND DEVELOPMENT MANAGEMENT

THIS MONTH'S CONTRIBUTORS

MERRITT A. WILLIAMSON
Burroughs Corporation

Merritt A. Williamson received his B. S., M. S. and Ph.D. in metallurgy from Yale, a Master's degree from California Institute of Technology in Aeronautics and one from the University of Chicago in Business Administration. Now with Burroughs Corporation, he is a lecturer at the University of Pennsylvania where he teaches an evening graduate course in the administration of research.

FRANK J. BIONDI
Bell Telephone Laboratories

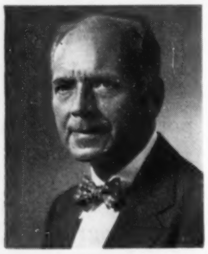
Associated with Bell Telephone Laboratories for the past 19 years, Frank J. Biondi has worked on insulating materials, structural plastics, barrier development for the gaseous diffusion isotope separating process of the Manhattan Project and electron tubes. He is currently active in ASTM committees and is vice-chairman of the Electronics Division of the Electrochemical Society.

RICHARD G. KOPFF
Arma Corporation

Cited by Secretary Forrestal for war-time training results, Richard G. Kopff established the described activities at ARMA in February 1952. He was formerly Industrial Relations Consultant at Ebasco Services, N. Y. and was Officer-in-Charge, Airship Training Center, Lakehurst, N. J. and Training Officer on the staff of Naval Airship Training with the rank of commander.

IVAN SIMON
Arthur D. Little, Inc.

Ivan Simon, D.Sc. from Charles University, Czechoslovakia, spent eight years in the Research Laboratories of the Skoda Works, Ltd. in Prague. When he came to this country in 1948, he was a Research Associate in the Electronics Laboratory of M.I.T. Author of numerous physical publications, he is now in the physics department of Arthur D. Little, Inc.



JOHN GAILLARD
Management Counsel

Former staff member of the American Standards Association (ASA) and lecturer at Columbia University, Dr. Gaillard specializes in the organization of standardization work in companies. In 1954 he received the Standards Medal awarded annually by the ASA "for leadership in the development and application of voluntary standards".

RICHARD L. SNYDER, JR.
Potter Instrument Company

Richard L. Snyder, Jr. worked on computers at the Institute for Advanced Study and later at the University of Pennsylvania as Chief Engineer of the EDVAC Project. Later he became Chief of the Computer Research Branch at the Ballistic Research Lab of Aberdeen whose staff installed the ORDVAC and worked on the ENIAC and BELL Relay Computer. He is now a consultant.

RESEARCH & ENGINEERING

CONTENTS

Developments in R/E

Navy Contracts Guided Missile Systems

SILVER SPRING, MD. — Following the U.S. Navy's recent announcement that guided missile ships will join the fleet this year, Dr. G. Russell Tatum, general manager of Vitro Laboratories, disclosed that his company has been engaged for more than a year, under contract with the Bureau of Ordnance, on systems engineering for the U.S.S. Boston and Canberra. These heavy cruisers will be the first of their type with guided missiles.

"It is too often assumed," Dr. Tatum stated, "that the military services have their problem solved when research and development provide them with missiles of desired performance. In fact, the services must then tackle difficult problems of maintaining rapid and automatic fire of guided missiles of great size and weight against jet-speed targets and there are also many systems engineering problems in making all the components of guided missile installations compatible and operable. Without solutions of these problems, the best missile becomes a white elephant. Fortunately many of these problems have been solved, and the armed services are now obtaining fire control and launching systems that permit firing of guided missiles with fewer manual operations than with conventional ordnance."

Dr. Tatum also disclosed that Vitro Laboratories is assisting the Bureau of Ordnance in engineering guided missile systems for other unidentified ships.

Sample rods from a supply of the standard are placed in a sensitive photoelectric spectrometer (right), where the spectrum of the alloy is measured automatically by means of electronic circuits. The dials at left indicate the concentrations of the elements present in each sample.

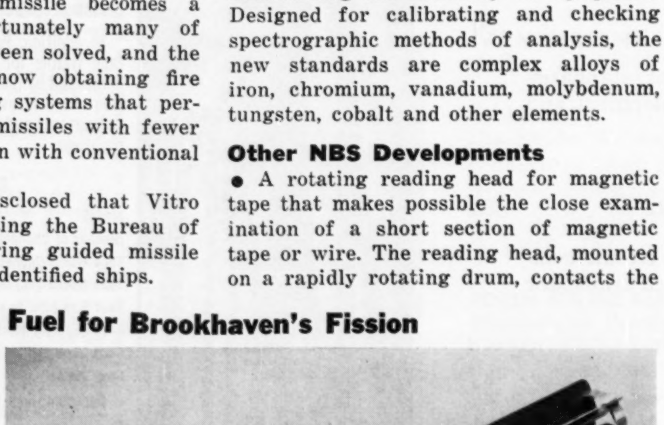
Spectrographic Standards For Research Labs

WASHINGTON, D. C. — Spectrographic standard samples of high-speed tool steels are now available from the National Bureau of Standards. Six different tool-steel standards, carefully analyzed and certified as to composition, have been added to the list of over 500 standard samples which the Bureau distributes to analytical and research laboratories for use in controlling chemical processes and maintaining the accuracy of equipment. Designed for calibrating and checking spectrographic methods of analysis, the new standards are complex alloys of iron, chromium, vanadium, molybdenum, tungsten, cobalt and other elements.

Other NBS Developments

- A rotating reading head for magnetic tape that makes possible the close examination of a short section of magnetic tape or wire. The reading head, mounted on a rapidly rotating drum, contacts the tape for a part of each revolution. Since the tape is held stationary, the head reads exactly the same set of signals once each revolution, and the playback can be continuously displayed on an oscilloscope for as long as desired.
- A compact, high-stability one-megacycle frequency standard, constant to a few parts in 10 billions per day. The standard employs an oscillator and a one-megacycle AT-cut quartz crystal unit in a bridge-balancing frequency-correction system. The standard produces a frequency almost entirely independent of tube, component and supply voltage changes. Because of its convenient size, use of relatively inexpensive and commercially available components, this secondary standard should prove a valuable tool in electronics and communications.
- A colorimeter for pyrotechnics smokes based on a system of color measurement adopted in 1931 by the Commission Internationale de l'Eclairage (CIE) reduces spectrophotometric data to color coordinates in three dimensional space. Colors are expressed in terms of three functions corresponding roughly to the three primary colors (red, green, blue).
- A type of statistical design that reduces greatly the effect of systematic errors in physical science experiments without increasing the number of measurements. Known as generalized chain blocks, the NBS designs require no more than two measurements for every experimental condition. They have been found very useful in studying the performance of tires, the heterogeneity of standard samples for synthetic rubber compounding, and the sorption of dextran to collodion membranes, as well as in an interlaboratory study of analytical methods.

Fuel for Brookhaven's Fission



Finned element of advanced design fabricated by Sylvania Electric Products Inc. will fuel the research reactor at the Brookhaven National Laboratory, Upton, N. Y. Approximately 30" long and 2½" in diameter, the fuel element consists of three aluminum covered plates bent at an angle. Each fin contains a layer of uranium-aluminum mix.

Battelle Develops:

- **Air Impurity Test**
- **Free-Flowing Rosin**
- **Paper-Coating Process**

COLUMBUS, OHIO—Battelle Institute has released details of three recently completed research programs: a new method for identifying minute concentrations of impurities in the air, a free-flowing form of stabilized rosin and an electrostatic process for coating paper.

The method for identifying impurities in the air involved "longpath" infrared spectrophotometry and has the advantage of being extremely sensitive and accurate. It is expected to be useful in air-pollution control studies and in the monitoring of industrial plant atmosphere.

The procedure utilizes the principle that specific substances in the air absorb certain wavelengths of light. Light is absorbed in proportion to the amount of the impurity in the air. Projecting a beam of infrared light through a 175-foot gap of air and measuring the type and amounts of light absorbed permits small concentrations of impurities to be analyzed.

The instantaneous method of identifying air contaminants has other possible uses. It might be utilized in research aimed at evaluating the hazards to humans and animals of crop-spray residues remaining in the air after the mass spraying of agricultural acreages with experimental chemicals. It could possibly also be applied to prospecting for petroleum and natural gas, since it is sensitive to extremely minute quantities of vapors arising from the ground.

Stabilized rosin promises greater ease of handling because it has been pelletized and treated with a conditioner. Based on an iodine-disproportioned rosin, the pellets will not fuse up to 130°F and are stabilized against deterioration through oxidation.

Researching the electrostatic process for coating paper was conducted for the Bergstrom Paper Company, Neenah, Wisconsin. The new process, completely dry, eliminates the problems resulting from paper wetting in conventional coating systems. A prominent feature of the method is its adaptability to a large variety of coating materials and several types of finishes.

In the Bergstrom process, an electrostatic field drives a charged dust cloud of pigment and heat-sensitive resinous binder against a moving belt of paper. Heat "fixes" the coating by fusing the resinous binder and pigment to the paper.

Coatings from 32 to 20 pounds have been deposited on webs moving at rates of up to 100 feet per minute. Web speed probably will be limited only by the rate at which the electrical charge can leak off the particles deposited on the web.

Convair Constructs Mach 5 Wind Tunnel

SAN DIEGO, CALIF. — The $3,500,000 "blow-down" wind tunnel to be built by Convair Division of General Dynamics Corporation will have a greater supersonic range than any privately owned wind tunnel in the aircraft industry, according to Joseph T. McNarney, Convair president. The tunnel will test aircraft and missile models at subsonic, transonic and supersonic speeds—supersonic to Mach 5, or five times the speed of sound (about 3,800 miles an hour at sea level). As it is now designed, the tunnel will be capable of test runs ranging from 50 to 90 seconds.

While some other non-industrial research tunnels create velocities in excess of Mach 5, these have much smaller test sections than the 4 x 4 foot test area in the new tunnel. Convair will now be able to conduct wind tests on a new airplane or missile design in a few weeks.

Six cylindrical tanks will store 28,000 cubic feet of air under 600 pounds pressure per square inch—the equivalent of 42 atmospheres and more than a million cubic feet of free air. An electronically controlled valve releases this pressure into a settling chamber where four screens comb the turbulence out of the air before it flows into the flexible nozzle of the tunnel.

The 38½-foot-long flexible nozzle will be constructed of a four-foot wide stainless steel plate approximately an inch thick. Stainless steel vertical walls of the nozzle will be rigid. Hydraulic jacks, operated remotely from the control room, will flex the top and bottom plates to form the desired nozzle contours which, with the electronically controlled air pressure, will determine the speed of air though the test section.

The supersonic test area—that in which the models are positioned at various angles in the air stream to measure electrically the internal and external forces upon the model—will lie in the last six feet of the nozzle before the air enters an adjustable diffuser and is slowed down. To make it easy for engineers to place and remove models for testing, the fixed diffuser will telescope to expose the model.

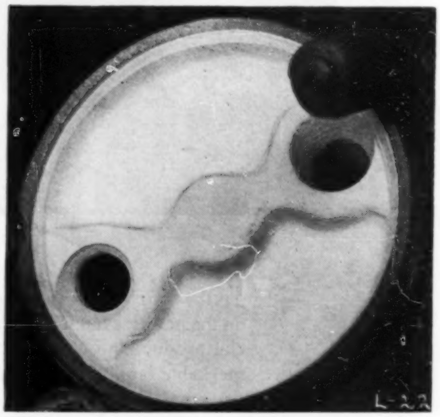
Oxide Coatings For High Temperature Applications

WORCESTER, MASS.—A new family of refractory coatings, called Rokides, that can protect base metals from temperatures above 3000°F and erosion effects of supersonic velocities has been released by the Norton Company. The oxide coatings can be applied successfully to almost any rigid material that withstands temperatures up to 800°F.

Rokides are hard, adherent, insulating, refractory coatings developed for use in rocket motors requiring protection from the very high temperatures, erosions and corrosions of combustion gases. The coatings are applied by a process similar to metalizing. Development of the process involved basic redesign of a metalizing gun to extend its function to this application. Coatings in the range of 0.005" to 0.100" thickness can be applied and accurately controlled by this technique. About 15 square inches of coating 0.010" thick can be applied in six minutes. No special skills are required and there is no limit to the shapes and sizes of parts that can be coated.

To promote adherence, which is largely mechanical, the surface of the material to be coated is roughened by an abrasive blasting operation. Low densities of the oxides do not add appreciably to the weight of the materials coated. Limitations of the coatings are: brittleness, a characteristic of all ceramic materials; porosity resulting from the method of application; and low thermal expansion as compared with that of the base materials on which they are applied.

The compressive strengths of the oxides are about ten times greater than their tensile strength, indicating the material withstands much more stress in compression than in tension. As a result coatings on concave surfaces withstand many more heating cycles than coatings on convex surfaces. Although the oxide coatings give great protection to the base metal, porosity of the coating does sometimes permit slow permeation of corrosive agents to the metal. Ideally, the thermal expansion of the coatings should be close to that of the base metal, preferably lower than higher.


Rocket nozzle with a ten thousandths coat of oxide at throat and back area.

The excellent properties of oxide coatings have suggested many new commercial uses for their application: dust collection systems, gas turbines, oil burner nozzles, thermocouple tubes and missile skins are some of the uses under consideration.

In the starred area above, construction has started on the new five million dollar plant for the commercial production of the Nitroparaffins and their remarkable family of derivatives. The new plant, the first major step in the company's Nitroparaffin expansion program, is expected to go on stream August 1955.

Located at Sterlington, Louisiana, the new plant is surrounded by CSC's great petrochemical facilities, from which such useful and basic products as methanol, ammonia, and nitric acid flow to all industry. In addition to the new NP plant, existing facilities at Peoria, Illinois, are being expanded.

Virtually laboratory curiosities a few years ago, the Nitroparaffins have been under study since 1935 in a continuing program of experimental production and evaluation. The four Nitroparaffins and six derivatives, which have already been produced and been proven useful in a wide range of applications, represent only a small fraction of the total number of derivatives under current investigation. The new chemicals represent a unique field of organic chemistry and hold unusual promise for virtually every industry.

The experience of Commercial Solvents Corporation in evaluating these versatile chemicals is available on request to every manufacturer.

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NBS Research Improves Three Chemical Processes:

- **Leather Impregnation**
- **Cermet Coatings**
- **Glass Fiber Paper**

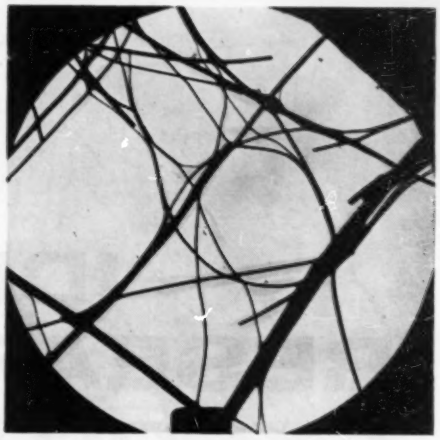
WASHINGTON, D.C.—Research at the National Bureau of Standards has produced marked changes in three industrial processes. Significant improvements in leather impregnation techniques have resulted from pilot-plant studies in which varying the impregnating process produced long wearing leathers with various degrees of water-proofness, flexibility, water-vapor transmission and appearance.

Experiments studied the effects of temperature, concentration of polyisobutylene and time of impregnation on the extent of deposition in vegetable-tanned crust leather. The amount of polyisobutylene deposited was found to be a linear function of the concentration of the polymer in the impregnation solution. When certain hard, low-molecular-weight resins are blended with polyisobutylene or Butyl rubber in the impregnant, leather of almost any desirable stiffness can be produced.

Substitution of other polymers for polyisobutylene also provides economic advantages as many of these materials are less expensive than polyisobutylene. The blending resin may be regarded as a diluent or solvent for polyisobutylene, or the latter may be considered as a plasticizer for the harder resin. Polymers recommended for blending with polyisobutylene included coumarone-indene, semi-hard hydrocarbon resin and polymerized resin.

A common type of cermet coating may now be applied rapidly and economically to a metal base. The cermet powder in this case is a chromium-boron-nickel mixture that is combined with a ceramic frit. The process employs ordinary ceramic coating procedures to replace the former flame-spraying method and provides a hard, high-temperature-resistant facing for metal parts. Coatings have excellent thermal shock resistance and are reasonably ductile.

In the NBS process, a slip is prepared from a cermet powder and a ceramic frit. However, instead of flame-spraying the material, the usual ceramic coating procedure is followed and the slip is applied to the metal part at room temperature by either dipping or spraying. The part is then fired at a temperature above the melting point of both the cermet and the frit. During the firing the ceramic phase in the coating serves as a flux to permit welding of the cermet particles without the necessity of a highly-purified, oxygen-free atmosphere.



Electron micrograph of the higher-strength glass-fiber papers shows small quantities of gelatinous binding material at most of the fiber intersections. The gelatinous layer, which results in greater strength, was formed by the addition of sulfuric acid to a pH of 3.4 during the paper making process (x6600).

All-glass paper eight times as strong as that first made in 1951 is now a reality. Because of its greater strength, this paper should prove more convenient for those uses such as gas masks, chemical filters and electrical equipment where the unique properties of the all-glass paper have already made it particularly valuable.

Improvements made in the process increase the tensile strength to more than 300 lb/in^2.

Heart Microphone, Skin Thermometer Aid Research

WASHINGTON, D.C.—Two firsts in instrumentation for medical research—a skin thermometer and a heart microphone—were demonstrated by the Vibro-Ceramics Corporation, an associated company of Gulton Industries, Inc., of Metuchen, New Jersey.

The instantaneous skin thermometer measures minute changes of temperature in the human body so sensitive as to record those that might occur from the inhalation of cigarette smoke or even the response to an emotional stimulus. The thermometer consists of three basic components: a temperature-sensitive thermistor mounted in a probe, an electrical bridge network which powers and operates the necessary circuit and a precision electric meter calibrated in temperature.

Heart microphone is encased in upper end of coiled cable. Lower end of cable terminates in a connector which can be attached to an electrical measuring device.

Capillary temperature measured by the new instrument is important in revealing information about the entire circulatory system, especially arteriosclerosis and obstructive vascular changes.

The subminiature microphone for recording undistorted sounds within the human heart, is probably the smallest operative device of its kind in existence. It was originally developed in response to the need for a fully sensitive instrument to aid in diagnosing congenital heart disease.

The microphone consists of a pressure pickup in a tiny metal cylinder about ¾" long mounted in the end of a cardiac catheter tube with a 0.09" diameter. Pickup is a minute strip of piezoelectric ceramic transducer electrically polarized and attached to a pair of wires connected to an electric recording meter.

In operation, the microphone end of the tube is inserted into an artery of a patient and finally passed into one of his heart chambers where it produces an electrical signal exactly proportional to instantaneous changes of pressure or vibration graphically or audibly recorded. The frequency response of the microphone ranges from a few cycles to 10,000 cycles representing approximately the entire range of human hearing.

Carborundum Creates Ceramic Fiber Project

NIAGARA FALLS, N.Y.—A Ceramic Fiber Project has been established as a new operating unit of the Carborundum Company; the new unit will manufacture high-temperature fibers finer than human hair and will develop new products and conduct physical and market research. Otto R. Stach has been appointed project manager.

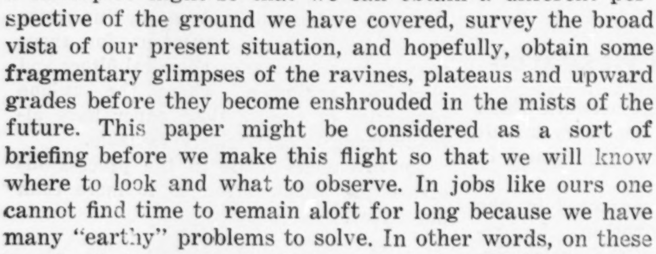
The new project will develop production techniques and applications of ceramic fibers, known as Fiberfrax. Since its introduction in 1952, the product has been in pilot plane manufacture. The ceramic fibers are used for insulating, soundproofing and gasketing of jet engines. They are also used as insulators and filters in the electrical, papermaking, industrial heating and chemical fields.

As blown from molten aluminum oxide and silica, Fiberfrax fiber is a cotton-like mass of extremely fine fibers arranged in random fashion. It remains stable at temperatures as high as 2,300 F.

The IDEAL RESEARCH EXECUTIVE

Merritt A. Williamson
Manager Research Division
Burroughs Corporation Research Center

It seems appropriate occasionally for those of us engaged in the management or administration of research to pause and ponder our professional positions. We need to get away from the detailed terrain of our jobs and take, as it were, a helicopter flight so that we can obtain a different perspective of the ground we have covered, survey the broad vista of our present situation, and hopefully, obtain some fragmentary glimpses of the ravines, plateaus and upward grades before they become enshrouded in the mists of the future. This paper might be considered as a sort of briefing before we make this flight so that we will know where to look and what to observe. In jobs like ours one cannot find time to remain aloft for long because we have many "earthy" problems to solve. In other words, on these imaginative surveys our fuel supply is low. If this preview helps you to see your job in a different light and helps to make your operation more profitable, it will have served its purpose.



The "Dodo" and the "Roc"

The first statement, and it cannot be made too soon, is that there is no such animal as an Ideal Research Executive. He is not, however, like the dodo who has become extinct, but rather like the roc, who from time immemorial has existed only in legend. What, then, you ask, can be gained by reading this article which bears the title of a specimen of homo sapiens who is not a *"has-been"* but, even worse, a *"never-was"?*

In science and engineering, far more than we realize, we use idealized concepts. This is particularly true for us administrators since we quite often need to be briefed on the high spots of scientific investigations and do not have time to go into all of the details which, after all, comprise the departure from ideality. Fascinating and important though they are, we just cannot take too much time with them.

Surely you remember the ideal gas from your elementary physics or chemistry. From the point of view of the kinetic theory, we define an ideal gas as one in which (a) there are no forces between molecules and (b) the molecules fill no appreciable portion of the space occupied by the gas. These assumptions permit the molecules to be treated as mathematical points incapable of rotation, and hence the degrees of freedom they possess are the three associated with motions of translation. There is, of course, no such thing as an ideal gas, but no one who has studied the subject would seriously question the utility of the concept.

Similarly, let's define our impeccable "roc".

> **"The ideal research executive (research director, research manager, vice-president in charge of research, or whatever title you wish) may be defined as a person who with maximum effectiveness heads up a group of persons operating with maximum efficiency to produce research results of maximum utility resulting in maximum satisfaction to his employer with minimum expenditure of money."**

One can readily see why there is no such animal. Effectiveness, efficiency, utility and satisfaction do not have an inherent tendency to strive toward the maximum such as we

are told entropy does according to the second law of thermodynamics when applied to any real and hence irreversible process. Nor does the expenditure of money show any tendency toward minimization as does the potential energy of a body when deserting a position of unstable equilibrium for a position of greater stability with correspondingly lower energy. The extent to which a research director approaches this definition might, then, be taken as a measure of ideality.

This definition mentions the executive's reaction with "a group of persons" and an "employer". Both of these ingredients may be altered by the action of the director within very narrow limits, but certainly we will all agree that they are not variables under his direct and immediate control. Since these two components sometimes change quite arbitrarily, it follows that the absolute possible effectiveness, efficiency and satisfaction attainable also change from time to time. When one considers the "inertia" of a research organization because of long established working relationships, fixed project objectives and absorbing personal interests, one sees that optimization is not possible as a practical matter even if the minute by minute behavior of the "group of persons" and the "employer" could be known in detail. Of course, as a practical matter, these are really never known, rarely understood and almost never predictable.

Common Denominator?

People try to single out some common denominator that could be recognized in all successful practitioners of the art (for it is far more an art than a science), but to my knowledge none of them has found any one thing that is common about them except their outstanding and acknowledged success. Of course, this is the resultant of many factors. At the Fourth Annual Conference on the Administration of Research held at the University of Michigan in Ann Arbor in September 1950, an entire session was devoted to the subject, "What Is Needed in a Research Executive?" This was followed by a stimulating round table discussion. In fact, wherever directors congregate, conversation quite readily drifts to the unique features in

the job of each which makes special demands on the executive's skill.

Lists have been made of critical requirements for executives, and they are worthwhile and interesting. If a hundred candidates were being examined for a job as research executive, they could be arranged in any order or grouping depending on what the test was constructed to reveal. But comparing persons is quite different from selecting with precision the proper person for the job and predicting accurately how the selected individual will make out on the job. Success is very intimately tied in with the organizational and personnel situation in the company where the man is going to work. It is easy to visualize a bar chart constructed from test and interview scores designed to give a "profile" of the candidate. A bar chart profile of the environment could be so indexed that the two profiles might be "fitted" into the "vacancy". But only the visualization is easy; the work would be of monstrous magnitude because of all the variables. But it is not beyond the realm of realization as our knowledge of organization, personnel testing, social intercourse and data handling extends.

Environmental Factors

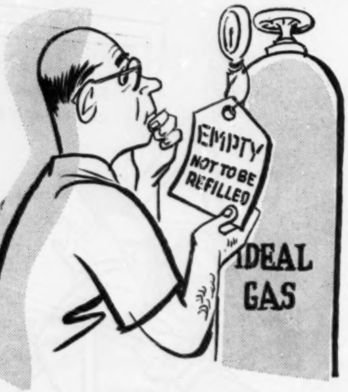
Many of the pertinent environmental factors are not recognized, and many that are recognized prove to be elusive upon examination. Yet they may spell success or failure on the part of the executive. Let's look at these in greater detail.

Companies sponsoring research activities might be divided into three rough categories: small, medium and large. A man highly successful as a director of research in a small company where the president drops in daily to see how the work is coming along and makes the majority of policy decisions might well prove a misfit if he were transferred to a larger organization and had greater responsibilities. The converse might also hold true.

On the other hand, companies might be divided into publicly owned or privately owned businesses. The kind of ownership might have a distinct bearing on the techniques necessary to secure enthusiastic management support of research.

The position of the research activity in the company is another vital factor—whether it is directly under the President as a staff function or whether it is under the Chief Engineer in the line. An executive successful in one spot might well become a misfit if moved to another.

The type of "research" work done also plays an impor-



tant role. The proportion of time devoted to fundamental research, exploratory research, applied research, trouble-shooting, development and service work is important. An executive outstanding in his job heading up work which is largely development might be entirely baffled and discontented if suddenly transferred to a fundamental research organization where he saw no hardware produced but only reports, and where no opportunity was provided to see any of the results applied.

Company policies on working hours might also spell success or failure. A man accustomed to working inspirational hours would not be happy or last too long in a spot where company policy established years ago decrees that the working hours are eight to five and the executives generally confer at eight in the morning.

The attitude of the rest of the company toward the Research Department is also important. In the company where research has recognition and is patronized to the full, the problem of directing is vastly different from the company where it is in active competition for funds with engineering and where the reception by the manufacturing department is reluctant if it exists at all.

The list of environmental factors could be expanded at greater length but those cited should suffice to show that a director cannot be evaluated except in terms of his environment, and any attempt to predict the success or failure of a person on a job must take into account more than the inherent aptitudes and capabilities of the individual.

Role of the Supervisor

One of the most influential factors is the person to whom the research executive reports. Does he make policy? Does he want from the research department what the director wants from it? Does he leave it up to the director to direct research? Does he want a man with ideas or does he want to be the prime generator of ideas? Does he understand the uncertainties associated with research? Does he expect the director to be primarily a scientist or an administrator? What opportunity does he give the director to see the broader aspects of the business? Does he encourage integration with the rest of the plant or does he want an "ivory tower"? The research executive's supervisor is a most definite part of the environmental profile.

Now let's examine the research organization under the director. Do the key men look for an eminent scientist in their director or do they prefer someone who will fight through budgets and appropriations, make personnel policies and act as a filter to those influences which are apt to impinge at random and disrupt steady progress? Do they insist on one in command who is "one of the boys" or will they work for an "outsider"? This group can be more readily changed by the director than any other. Key personnel can be shifted, jobs redefined and the philosophy of operation changed, but not overnight. If it takes too long for a new man to effect expected changes in the environment, results will not be forthcoming until too late. The first year's operation for a director in a new spot is most critical.

Whether or not the research department is well established or just being organized is also important. Certain persons are born organizers and promoters, but if left in an organization too long they can certainly impede progress by making changes so frequently that steady forward progress never results. A rugged individual with a mania for reorganization might do well to consider this trait before going into a job where gradual and infrequent changes are traditional. So, too, a man trained in an environment of order might fail miserably if he worked in a chaotic organization requiring fast and fancy footwork. These factors of environment are certainly important when matching the job against the individual's profile.

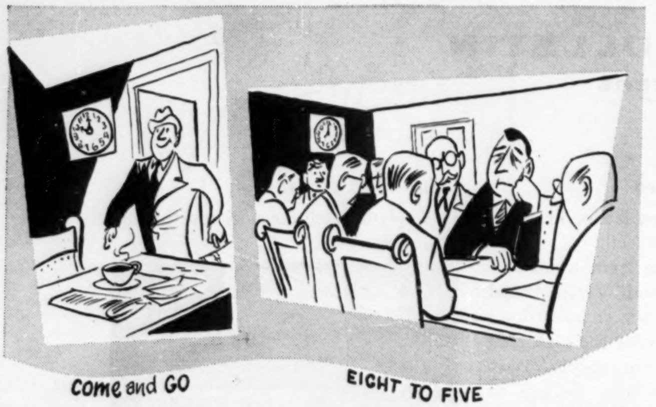
Such is the background and the folly of interchanging at random personnel from one setup to another. Consider in some detail the director and his immediate staff; these cannot be discussed well separately since a real live successful director, as opposed to an ideal director, may be very weak in certain areas. If he knows what they are, he may then surround himself with staff men to supplement these deficiencies. It can truthfully be said that the office of the director must be in possession of the following abilities: scientific attainment-generation of ideas, administrative ability and salesmanship.

Attributes For Success

Rare is the man who possesses all three and rare is the situation in which he can function effectively in all three departments even if he were qualified. Our "Ideal" research director would, of course, be entirely at home in any of these roles. Our action man, if he were successful, would recognize where he needed greater talent, plan his organization and delegate responsibility accordingly.

In his office, then, or on his staff must be represented the following attributes:

1. Vision for future planning to shape the course of the company's business in the future.
2. Ability to make and adhere to policy decisions in areas where the rest of management is reluctant to formulate any pronouncements.
3. Organizational ability to place each worker in a position where he can produce with greatest effectiveness, and to subdivide his department into workable units, sections and divisions so that proper authority may be recognized and the smooth flow of work and ideas can take place.
4. Executive ability to get jobs done and to carry out policies that are either of his own making or received from higher authority.
5. Administrative ability by proper delegation of operational and repetitive details in order to free the time of valuable scientific personnel so that they can carry out their work unhampered by troublesome routine.
6. Scientific ability to evaluate the work of the division and to stimulate high caliber scientific investigation.
7. Engineering ability to provide the necessary balance to the purely scientific work by insuring economic evaluation and production practicability of the resulting research.

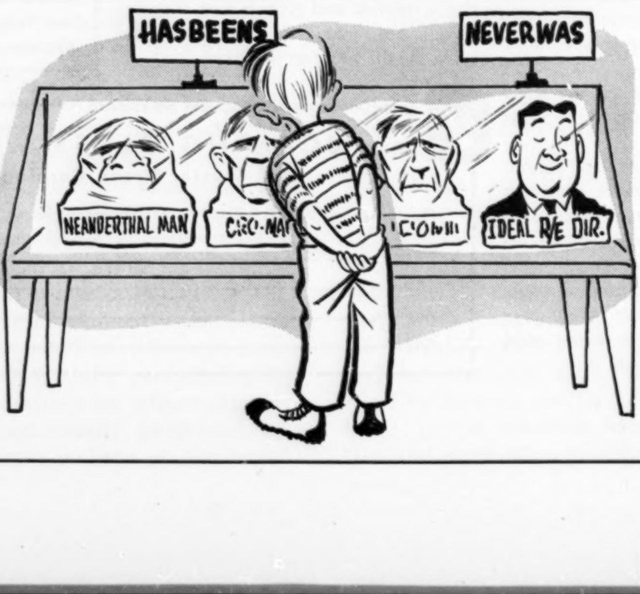


8. Business ability so that the division may be integrated with the rest of the company and through this knowledge provide a vital service to the company by representation on the board of directors if invited.
9. Legal knowledge as it applies to personnel problems, patent procedures and possible patent infringement suits.
10. Salesmanship or the ability to present information so that it results in the desired action. In some companies this is best accomplished through a reputation of honesty, personal integrity and reliability. In others it may best be accomplished by showmanship. "Salesmanship" may be a poor word choice since it may connote passing out cigars, making wild claims, using high pressure tactics and, unfortunately, failing to adhere to scientific ethics. Perhaps "persuasion" would be a better term for this attribute.
11. Diplomacy, tact or discretion. Someone in the director's office should be able to smooth out the rough spots and get action from others over whom they have no control. This is important internally in the smooth running of the division.
12. Scheduling and following up. Someone must not allow work to slide by undelivered or to continue when it is no longer needed.
13. Attention to details. Someone should be able to get as detailed as is necessary in talking to the men about their work. Someone, and perhaps the same person, should never get too detailed in presentations to management.
14. Attendance at meetings. Someone in an important position should attend public meetings to keep the company constantly before the public in a favorable and progressive light. These public meetings may be technical society meetings or general management meetings. Sociability is a great asset.
15. Research directors should also participate actively in internally sponsored company meetings. This is very important if the rest of the company is to feel that the Research Division considers itself a part of the overall operation and not a sanctuary set apart.
16. Someone in a director's office should be genuinely concerned with the professional upgrading and stimulation of personnel. This is absolutely essential if the research division is to have continued vitality.

The research executive's task would be easy if he had all of the qualifications listed above. He would not only have the technical ability, but he would have his division so well organized that he would have time to give attention in the right degree to all of the myriad functions which his position demands. He would also be farsighted enough to have prepared well in advance data which would make the job of selling research quite easy.

Just one last specific point about the ideal research executive. He is in a position where he must interpret science to business men, and in turn, interpret business requirements to his working scientists. It is difficult to be an effective translator since information coming from either direction must be rephrased, re-interpreted and resold. The effectiveness with which these interpretations are made might perhaps be taken as another measure of his ideality.

In summary, we have seen that the ideal research executive does not exist, but the concept serves to keep before our eyes a few of the more important aspects of the job. We have made the point that the performance of a man in a specific job is a function of his own qualifications, those of his immediate staff and the environmental factors surrounding his position. We may take heart in the fact that an ideal research director does not have to exist. An ordinary mortal can do a very effective job if he sees clearly his own weaknesses and limitations and so organizes his division that no vital functions are neglected. The Research Director does not have to know all the answers, but he must know how to use people, and he must be the foremost planner in the entire business operation. Ours is a challenging profession, and one which is richly rewarding both to the man whose profile fits the "vacancy", and to the company whose requirements are supplied by the proper profile.



ADVERTISEMENT

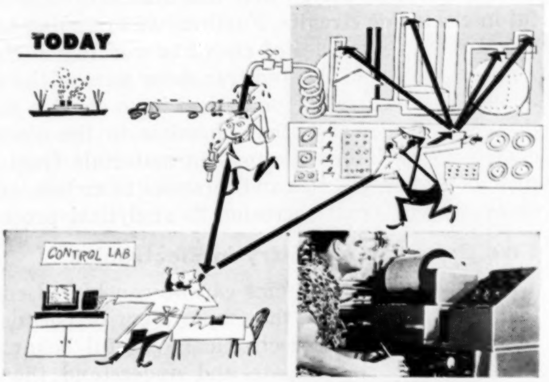
Analysis Moves from Lab to Line

The pride of the automation proponents is the chemical processing plant. Carloads of materials flow through its complex network of pipes into gleaming fractionation columns, purification towers and reactors with a minimum of human attention. Equally large amounts of finished product flow outward without ever having been seen by human eyes.

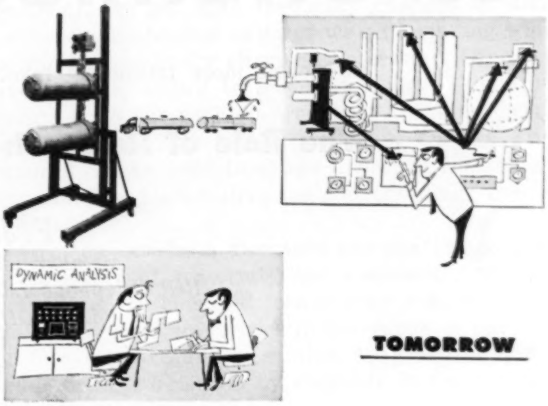
This complex system functions smoothly thanks to the hundreds of control instruments in any processing plant. They control material flow, they provide the correct temperature and pressure to produce the highest product yield. These plants represent our closest approach to the automatic factory.

But in this system there are flaws. For even when all dials and gages are functioning correctly, the product yield in terms of quality and quantity may be completely awry. These instruments will not indicate changes in raw material composition, catalyst contamination, or loss of efficiency in a scrubbing tower. Present-day instruments indicate only the process stream environment, not the composition of the process itself. Only the control laboratory is able to give us an accurate picture of the product and its composition as it moves through the plant. Subtle deviations in the product can be spotted and analyzed, and from the control laboratory instructions can be forwarded to process areas prescribing changes in control instrument settings. Thus, true control in today's processing begins in the analytical laboratory.

TODAY



But efficient as they are, control laboratories still represent a bottleneck in the processing chain. It takes time to move a sample to the laboratory, analyze it, and relay findings back to the plant. Meanwhile, vast quantities of product may have moved through the processing units.



TOMORROW

An obvious solution is to move the laboratory to the problem, i.e., tie an analytical instrument like the infrared spectrometer directly into the process stream where it can produce continuous and instantaneous data. Instruments capable of providing such "on-stream analytical control" are just beginning to appear. They will not replace existing environmental controllers but they do provide the means for automatically controlling these instruments to meet changing process stream conditions. They close the loop between the product and the process stream environment in which it is produced.

Two such on-stream analyzers are already in production by Perkin-Elmer and are being used in the field. Known as the Bichromator and Tri-Non Analyzers, each has its use depending upon the particular problem to be solved. While the most obvious application for such analyzers is to monitor the finished product, in a complicated chemical process where there are many variables, end point analysis does not provide sufficient control information. Hence, it is found advisable to install instruments at several critical points in the process. Such analyzers will soon make true automation a reality in chemical processing.

Digest of an article from *Control Engineering*, Oct., 1954.
Reprints available from Perkin-Elmer on request.

THE PERKIN-ELMER CORPORATION, NORWALK, CONN.
First in Analytical Control

Chemical industry has scarcely noticed the extent to which research chemistry has grown in electronics and has not to date seriously flexed its capable muscles toward needs in this field. Ultrapure materials, materials of controlled impurity, materials for abnormal ambient conditions, specialized chemical tools with uncommon sensitivities are but a few. Here, a research chemist presents a

CHALLENGE to Chemical Research

to become more intimately involved with these needs by spelling out

The Role of Research Chemistry in Electronics

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In general the chemical industry has not been deeply involved with the problem of the electronics industry—a result partly of the specialized and relatively small volume needs of the electronic device industry and of the inability of the electronics industry to specify their needs without resorting to elaborate electronic tests. Further, there is an explainable wide range of raw material requirements in the electronics industry which is not well understood by the chemical industry. A real challenge exists in this area for both industries to understand one another.

The electronics industry is currently intimately dependent on a relatively small group of chemists working within the industry for the control of its vital raw materials and for the development of processes to adapt these materials to electron device uses. Further, these chemists are, in cooperation with electronics engineers and physicists, broadly seeking to understand the nature of electronically-active impurity-dominated materials and their life patterns and functions in electronic devices.

Research Area

Electronic devices and their associated circuitry are necessarily made of materials. In many cases these materials are very carefully chosen and control the electronic functioning of the devices. It follows that electronics and materials have a close kinship. Those who deal in materials are generally called chemists and include metallurgists, ceramists, electrochemists, physical chemists, analytical chemists, organic and inorganic chemists.

If we examine the interests involved, we find on one extreme the circuit designer, who is little concerned with materials except when they limit the types of devices available to him or when his circuits do not perform as expected due to failures or misperformance of the circuit components. At the other extreme we find a large group of chemists, in the chemical industry, who are interested in a great variety of materials of commerce and who are concerned with many properties, only a few of which may be related to electronics. In this discussion we are not going to be too concerned with these two extremes. Rather we will discuss the role of chemistry in the area where the chemist and electronic device designer rub shoulders to invent, develop, design and manufacture components useful in electronic circuits. Further, we are going to limit our discussion to examples of chemists working in close liaison with the electron tube and transistor part of the electronics industry. We cannot hope to deal in so short a review with the activities of the other chemists in the electronics industry whose interests range in materials from insulators such as rubber, plastics and ceramics to metals, and in processes ranging from corrosion to analytical procedures.

Five Roles of Chemistry in Electronics

Chemistry in electronics can be considered conveniently in five roles. First, is the employment of chemistry to aid in the discovery of electronically useful behavior in materials and to investigate and understand the nature of such phenomena. Second, is the role of chemists working closely with electronic designers to choose materials of construction for devices. Third, is the role of chemistry in processing of materials to render them useful in the device. Fourth, is the role of chemistry in determining the reproducibility of raw materials and processes to insure reliability of performance over a long life. The fifth role is the employment of chemistry as a diagnostic tool to examine devices to discern reasons for their failure in order to better understand the life patterns and thereby improve the device.

These roles pose a real challenge to the chemical industry, which has scarcely noticed the chemistry in electronics and has not to date seriously flexed its capable muscles towards this need.

Electronic Behavior of Materials

The first role of chemistry in electronics can be briefly illustrated by examining one electronic property of materials, namely the electrical resistivity.

Since electronics deals in general with the motion of electrons, the ability of materials to oppose such motion, the resistivity, is an important parameter. The materials

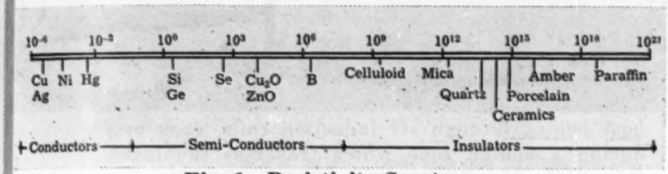

Fig. 1—Resistivity Spectrum

with high resistivities are used as insulators. At the other extreme of resistivity are the conductors which are employed to connect the various components of an electronic circuit. Between these two extremes are the semiconducting materials which are the very heart of electron devices such as tubes and transistors.

Figure 1 illustrates this resistivity spectrum showing the spread between insulators and conductors as an immense one covering 27 orders of magnitude.

Throughout this range, in addition to differences in resistivity, we encounter many other electronically interesting phenomena which are principally controlled by chemical and metallurgical techniques. In the semiconductor range are such elements as Si, Ge, Se, C, P and Te, and such compounds as BaO, CuO, ZnO, CdS, PbS, ZnS and literally thousands of others.

Semiconductors behave differently from conductors and insulators in three important ways. First, their resistivities decrease with increase in temperature at a rate of change 10,000 to 100,000 times as fast as metals which behave in the opposite manner. With a metal such as copper, one must raise the temperature to 300°C in order to double its resistivity. Secondly, the resistivity of semiconductors is sensitive to the addition of very minute amounts of impurities. Impurities barely detectable by the spectrograph may change the resistivity six orders of magnitude while in metals like copper resistivity barely changes in adding impurities until amounts of 10% to 20% are reached. In this respect a change in resistivity of the semiconductor may be a more sensitive tool than the more conventional chemical methods for the detection of impurities. A third difference between conductors and semiconductors is illustrated if one connects the terminals of a battery with two different conductors and reads the voltage and current flow. Reversing the battery connections will not cause any changes; that is, the current flows equally well in either direction. However, a semiconductor and a metal in contact may pass current easily in one direction and practically not at all in the other direction. The resistivity in one direction may be as much as one million times greater than in the other direction. In short, we have an electronic check valve.

Considering properties other than resistivity and materials other than semiconductors, ceramics such as $BaTiO_3$ have piezoelectric properties; that is, when deformed they will develop a potential and current will flow, and conversely as a potential is applied across such a material, the dimensions will change. If the potential applied is at a high frequency, we get high frequency changes in dimensions and have a mechanical agitator which is finding widespread use in ultrasonics for chemical processing. Other ceramics have been developed to absorb unwanted high frequency energy or to act as high frequency insulators which will not absorb or distort high frequency energy. Still other ceramics can be used to attain dielectric constants several thousand fold higher than the conventionally used organic materials.

In review, we have discussed one electronically interesting property of materials, the resistivity, which can be manipulated by chemical means over wide ranges by very small changes in impurities in the range of parts per million to parts per hundred million. Most of this chemical effort is being carried on by chemists in the employ of the electronics industry.

Processing Materials of Construction

The second and third chemical roles in electronics can best be illustrated by citing another example. Probably the

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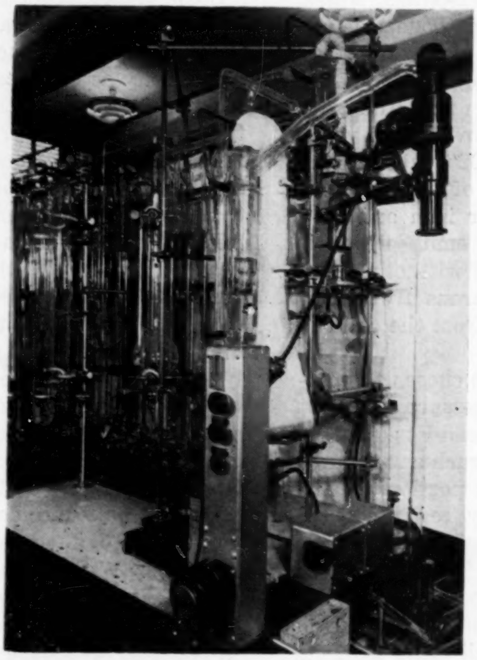


Fig. 2—A portion of the equipment used to measure gas content of metals by the vacuum fusion process.

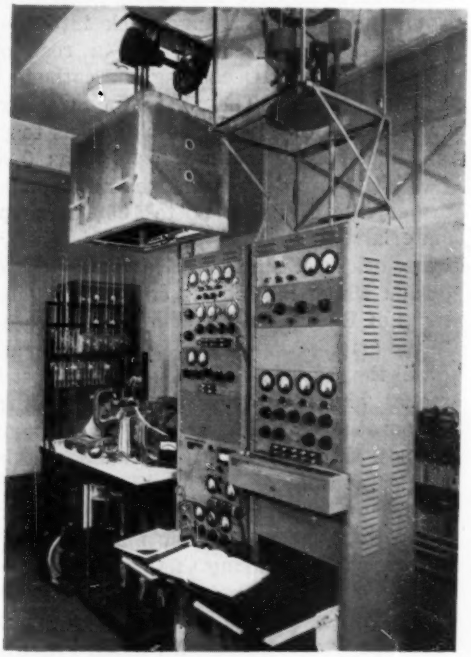


Fig. 3—A mass spectrometer used in the study of reactions occurring in the thermionic emission process.

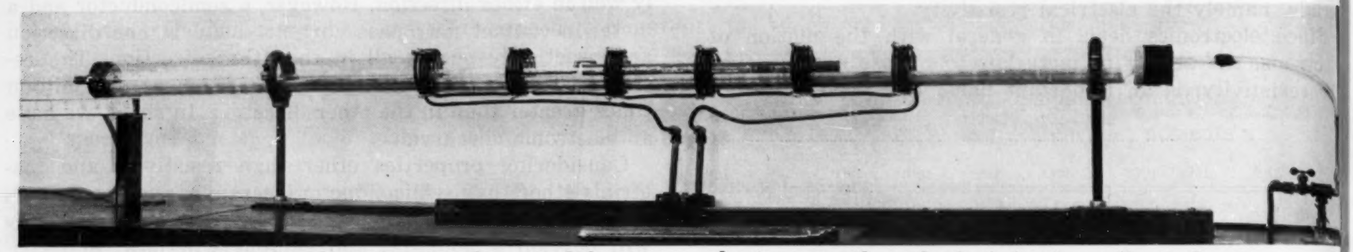


Fig. 4—Induction heated zone-refiner used for germanium. An impure germanium ingot in a graphite boat passes through six induction coils, each producing a molten zone which traverses the ingot.

most familiar electronic circuit component is the electron tube. Broadly speaking an electron tube consists of a source and a collector for electrons, between which is arranged a grid which has the ability to allow a small or large flow of electrons to occur depending on how the potential on the grid is changed by a signal imposed thereon. The heart of the device, the cathode or source of electrons, is a semiconductor. For efficient functioning we must properly house and support these principal elements. For example, to allow for ease of movement of the electrons without collision with gas molecules the elements must be in an evacuated bulb. The cathode must be heated to high temperatures (750°-900°C) to cause emission; that is, literally to boil out the electrons. The heater, operating at 1200°C, must be insulated from the metal cathode which it heats with little or no current leakage, imposing a real chemical materials problem. The cathode metals must provide reducing agents to react with the BaO of the cathode coating to form free Va as the impurity activator for the cathode. The collector of electrons, commonly called the plate, must be so constituted that while collecting electrons it does so without excessive heating; that is, it must be an efficient dissipator of heat. It must not have on its surface chemical compounds which form positive ions when struck by electrons, which would vigorously impinge back into the cathode causing either mechanical damage or a reaction with the free barium in the BaO causing the cathode to lose its ability to emit electrons. The modulator of electron flow, the grid, must be metallurgically so chosen as to provide stiff wires of dimensions sometimes as fine as 0.0002″ in diameter (1/10 the size of a human hair), capable of being wound to very close pitches up to 1000 turns per inch and of a material which will not itself easily emit electrons when heated. Such grids are usually coated with other materials which inhibit the emission of electrons from mixtures of Ba and BaO that may evaporate from the cathode to the grid.

All the materials of construction must be chosen to operate at high temperatures and at low pressures without evaporating metallic or gaseous impurities. For another purpose thin films of gas adsorbing metals such as mixtures of Ba, Al and Mg must be evaporated on portions of the inner surface of the tube to "getter" any residual gases in the tube or gases which may diffuse from the materials of construction during the life of the tube. The glass of the envelope and the metal to glass seals used to lead wires through the glass walls have some important chemistry and metallurgy associated with them. Finally all these elements must be held together and insulated from each other at the high temperatures involved without losing too much heat or distorting and attenuating high frequency signals brought in on component parts. For this purpose thin mic stampings have been traditionally employed. However, fo modern high frequency tubes the amount of gaseous con taminants found in natural mica is beginning to limit th further usefulness of natural mica and causing the electro tube chemists to search for more stable insulators such a ceramics and synthetic micas.

Insuring Reproducibility

To illustrate the fourth role of chemistry in electronic we find that most of the tube elements are not available a items of commerce from the chemical or metallurgical in dustry and must be specially treated by chemists in th employ of the electronics industry to adapt them for use In fact most raw material suppliers have little appreciatio of or ability to assess the electronic or electrical behavio of the materials they supply to the electronics industry an must rely on that industry to advise them of the accepta bility of their product. This is aggravated by the small siz of the electronic devices and, therefore, the relatively smal demand for certain raw materials, making suppliers re luctant to invest in any elaborate testing techniques.

Some of the larger electronic manufacturers have had t set up chemical operations in their own plants to insur themselves a reproducible supply of raw materials. The in turn act as chemical supply houses to their smaller as sociates in the industry. While this is a real challenge t the chemical industry, it is not all one sided, since in man instances the electronic behavior of a raw material is a more sensitive test of its suitability in electron device than more conventional chemical tests. Industry-wide com mittees, such as those sponsored by the ASTM, are en deavoring to bridge this gap by relating chemical proper ties with electronic behavior.

At the base of the problem is a need for more sensitiv methods for chemical analysis. The need for such new ana lytical techniques of enhanced sensitivity is in many case not felt in the chemical industry. Further an inability t specify its needs to the chemical industry in chemical term causes the electronics industry to a large degree to engag in batch approval testing; that is, small samples of a ma terial are built into devices and the behavior of the device compared to a currently used material or to referenc standards. With the great number of independent and inter dependent variables operating in the building and process ing of electron devices it is possible that such a batch ap proval test procedure may not be definitive.

Sales managers in the chemical industry have been puz zled by reports from electronics manufacturer A that a

continued on page 2

certain lot of materials is unacceptable, only to find that the same lot is acceptable to manufacturer B for essentially the same end use. Both electronics manufacturers A and B may be correct in their analysis of the suitability of the lot of material in question since their designs and processes can be different and still attain the same end product. This has been difficult for the materials suppliers to understand and calls for an educational effort on the part of the electronics industry.

In the purchase of electron tube cathode coating raw materials, mixtures of $BaCO_3$, $SrCO_3$ and $CaCO_3$, one chemical supplier was asked by a variety of electron tube manufacturers for at least six widely varying ratios of the carbonates in one mixture, varying amounts of allowable chemical impurities, different particle size ranges. Further some device manufacturers wanted the product made by a sodium carbonate precipitation while others preferred an ammonium carbonate process. The chemical supplier was obviously puzzled and concluded that the electronics industry did not know what it wanted. And since he has no independent manner of ascertaining suitability of his materials, his only hope is to repeat religiously his process using as best he can the same raw materials. Each electronics device fabricator tailors his designs and processes in such a way as to be able to use materials whose behavior is known. Reduction in the number of types of cathode coating materials will result from industry standardizations, but it is a slow process since large volumes of favorable experience are on hand for each species of material used by the various manufacturers and quite naturally there is reluctance to changes.

A similar situation in the variety of cathode tubing nickel alloys has been partially alleviated. Within the past ten years industry standardizing groups (ASTM) have reduced the number of alloys of nickel used in electron tubes from several dozen to substantially only three.

To assure a reproducible supply of raw materials, the chemist in the electronics industry first must carefully examine and devise methods of measuring the physical, chemical and electronic behavior of the materials. Many times he must pioneer in seeking to control impurities or measuring properties in ranges not of vital concern to the bulk of the chemical industry. This information he reduces to purchase specification form. Often he must specify a group of properties not of primary concern to him, but such an array of properties puts him in a position to know when a supplier has made a change in his process. This approach has paid real dividends, but is admittedly partially blind and should be considered at best only a stopgap until what is wanted can be actually defined in chemical terms. Finally, the electronic chemist acts as an emissary between his associates in the chemical and electronics industries trying to get each to see the other's problems and viewpoints.

After the electronics industry has purchased and accepted materials in accordance with specifications written by their chemists, the next role of these chemists in assuring a reliable product is to devise and control the processing of these raw materials to render them useful in the electronic device. Again in this area the electronics chemist can get little help from the chemical or metallurgical industries which do not feel his problems and needs. In many instances the properties he is concerned with have not been defined, and he must become his own expert and assemble fundamental data.

The electronics chemist must, with an understanding of the needs of the electron device designer, devise and operate processes which will remove unwanted influences and enhance or develop desirable features of the raw materials. For example, for cathode nickel he must devise methods for cleaning the nickel to remove dust, lint, contaminants such as iron, metal oxides and gases without at the same time changing the reducing agent content of the nickel or their state of chemical combination, for on these features depend the emission level and life of the electron tube.

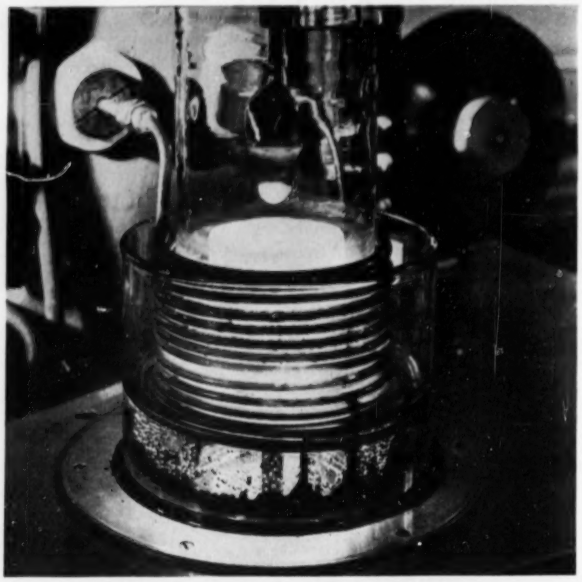


Fig. 5—A single crystal of germanium just after being grown by pulling from an inductively heated crucible of molten germanium, all in a controlled atmosphere.

Further the chemist must concern and familiarize himself with all phases of device manufacturing, for often the electronics engineer encounters a chemical problem whose effect on a product he may not realize.

Another role played by the electronics chemist is that of trouble shooting in manufacturing processes which, though seemingly carefully controlled, are producing an out-of-specification product. In this role he may discover unforeseen combinations of circumstances which pose a new chemical or materials problem. From such experiences he learns how to revise his materials or process specifications to prevent the problems recurring in the future.

Life Performance of Electronic Devices

With the electron device fabricated the chemist's role is still not finished. He must be concerned with the life behavior of the product, try to understand the aging phenomena which occur and collaborate with the electronic designer in predicting useful reliable life. One approach is to break down the complex electronic functions into simpler ones and to study carefully and try to understand these simplified structures and then to synthesize the more complex behavior pattern.

Upon these reliability understandings not only depend the economics of the communications systems, the faithfulness of electronic process control for industry and the enjoyment of our radio and television programs, but in many cases such as in military uses the security of the country

as well as life itself.

In discussing the role of the chemist in the electronics industry, we have referred briefly to that class of materials known as semiconductors which are the vital elements of most electron devices. Further, certain examples of the electron tube part of the industry have been cited to illustrate the chemist's role. Little has been said of the role of chemistry and metallurgy in the conductor and insulator needs of the electronics industry. For example, a large wire and wire insulating industry serves the needs of electronics essentially from the ranks of those industries. Organic and inorganic insulators, finishes, dielectric and magnetic materials are also supplied primarily from these industries. A small but essential group of manufacturers, while themselves not electronic device suppliers, provide vital specialized services in uncommon metals such as molybdenum, tungsten, tantalum, cathode tubing and thermionic filaments, and supply low loss ceramic insulators. Many of these small suppliers are essential links of the supply chain, and it is interesting to note that many are operated by chemists or metallurgists formerly directly active in the electronics business.

In the transistor portion of the electronics industry, and in particular with germanium and silicon transistors, chemists and metallurgists play an essential role. For example, you will remember that in electron tubes we literally must boil the electrons from our cathode system. In transistors on the other hand, the flow of electrons is between the atoms of the solid, and even at low temperatures we have, in properly prepared semiconductors, large quantities of electrons to control. Essential in the preceding sentence are the words "properly prepared". For example, germanium, a by-product of zinc refining, is converted to the tetrachloride and purified by fractional distillation, followed by hydrolysis to produce germanium oxide. The oxide, by usual chemical standards, is quite pure but would be totally unsuitable for transistor purposes. A bar of germanium produced by reducing this oxide would contain impurities in the range of one part in a million to one part in one hundred million (10^6-10^8). The metallurgists at Bell Telephone Laboratories developed a radically new process known as zone refining for further purifying this already pure material. In this process a small molten zone is made to traverse through the bar of germanium by moving the heating element. The impurities tend to concentrate in the molten phase and are thereby swept to one end of the bar. By such a technique the impurity content of germanium is reduced to one part in 10^{10} to 10^{11}. In short, the chemists and metallurgists in the electronics industry have produced possibly the purest commercial material known to man. Further the purity of this material cannot be ascertained by chemical means, but only by electronic means. This technique is potentially useful to the chemical and metallurgical industry in general for the purification of certain organic and inorganic materials and may well produce materials whose true properties have yet to be measured since they have never been produced in pure form.

With increasing numbers of chemists active in the expanding electronics industry, and as some of the newer devices such as transistors become mass produced, we can expect a better definition of the problems and perhaps added incentive for the chemical industry to become more closely involved with the electronics industry. Surely from such increased participation the chemical industry will not only aid the electronics engineer but will also reap benefits which can be applied to other chemical problems.

Do you have a large number of first year quits among your junior engineers? Here's how ARMA reduced them to zero by setting up a

FRAMEWORK for Engineer Development

Richard G. Kopff
Administrator of Technical Education
ARMA Division, American Bosch Arma Corp.

Through sheer physical necessity induced by the current national shortage of engineers and the volume and complexity of engineering projects most engineering firms are face to face with some serious personnel problems. They need more engineers, they need to train them faster, they are groping with problems of communication and organization, they are confronted with problems of increasing costs, and they are bothered with problems that relate to engineers as people.

Recognizing Bias

These are serious problems, but probably the most serious problem is one of which the average top engineering administrator is unaware. It concerns his personal bias toward these engineering personnel problems and, indeed, the bias of his whole organization—a difficult thing for any engineer or scientist become executive or administrator to admit to himself. His training has taught him to be "objective", to be "scientific."

Every company is organized and held together by some specific corporate purpose. However, specific psychological tendencies also hold a company together giving the people in it a bias in dealing with both internal and external circumstances that determines how they will respond. Interaction, the influence of relationships among people, develops effective mechanisms by which people modify each other's behavior. Adduced experimental evidence proves that the participation of people in these patterns of influence—and any engineer who works for any organization does so participate—definitely and specifically affects individual psychological processes, even such basic processes as perception and learning. These patterns of influence which grow within an organization actually determine *what* the individual, be he top management or engineer, will observe.

Thus Arma realized that any program which might be undertaken to meet engineering personnel problems faces at the outset the difficult problem of minimizing bias—not only in the solution of a problem, but more important in the determination of what *is* a problem.

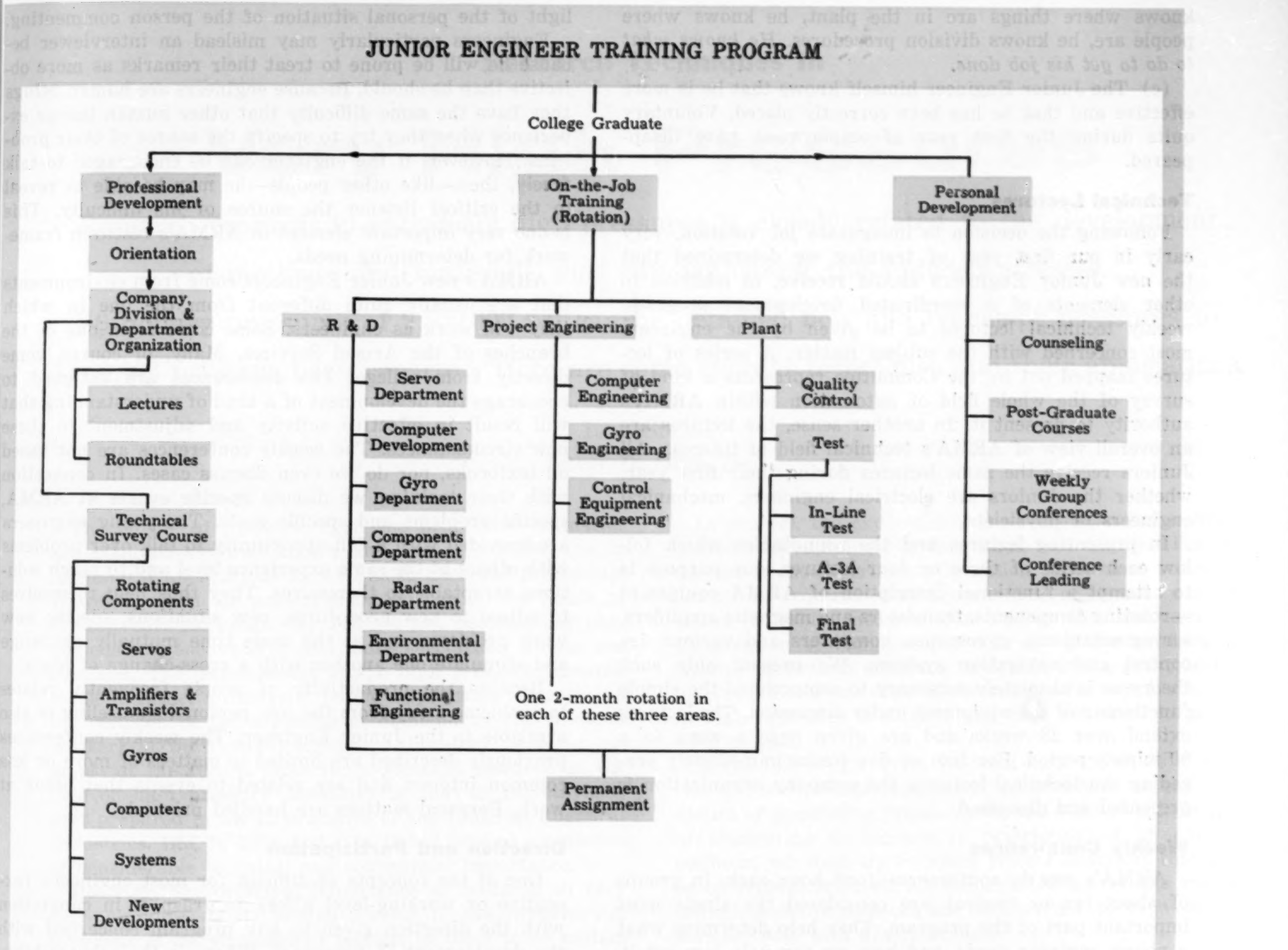
Developing The Need

Determining what is a problem is sometimes not as easy as it would seem on the surface, and solutions are not often quickly arrived at. Any effort to establish a successful framework for engineer development calls for recognition from the top that a problem exists, with a desire to exert a determined effort to define and resolve it. It should be realized, however, that needs are complex because human beings are complex. The chief engineering executive will do well to understand that progress in this direction is more appropriately characterized by developed understanding and skill than it is by any ready-made answers. There are answers, and some will be sketched herein, but since they have to be applied by specific executives in specific situations, each executive, each supervisor, each engineer must understand both the "why" and the "how" before intelligently directed and effective action can take place. A simple intellectual understanding of "basic principles" is not enough.

Perhaps because most top executives are intelligent, resourceful, decisive and self-confident, and because their success has been due in many respects to their ability to direct and control the activities of their subordinates, many of them find it difficult to sit down and analyze with their subordinates the problems involved in engineer development. Yet this is exactly what must be done very early in any such program for some fundamental reasons. We have mentioned the problem of minimizing bias. It is equally important to secure the involvement of department heads at the next level of supervision.

At ARMA, in connection with the establishment of a Junior Engineer Training Program some four years ago, by way of illustration, just as soon as needs had been explored with the Engineering Vice President, the first step was to create a Junior Engineers' Educational Advisory Committee, consisting of the Chief Engineer as chairman and eight major department heads as members. This Committee made a critical analysis of training needs, out of which came certain broad policies to meet these needs. Needs, therefore, reflected division-wide problems, and policies embodied the broadest experience that ARMA Engineering could contribute.

One result of this department head committee action (better: "interaction") is a more balanced program than any one or two men could devise. An important result is the growth of a feeling of personal responsibility in connection with the program on the part of each department



Outline of ARMA Junior Engineer Training Program. Needs should reflect division-wide problems, and the developed program should embody the broadest experience the company can contribute.

head, because he will have helped to create the program. Another reason for utilizing this type of committee action is that it fosters an understanding of problems larger than those of any single department and develops with that understanding a feeling of responsibility toward such problems. While this can occur in periodic technical staff conferences, an engineering organization does not usually provide such opportunities at regular and frequent intervals to discuss the development of engineers. And yet related to this are such problems as output, costs, creativity, efficiency, turnover of personnel and the like.

Job Rotation

One of the first decisions of ARMA's Junior Engineers' Educational Advisory Committee was to establish a rotation program. In general the goal is to give a Junior Engineer in his first six months with ARMA some exposure in each of three major areas prior to permanent assignment: research and development; a project engineering department; and a plant type of engineering, such as quality control or test. Each Junior Engineer gets three different two month job assignments. Permanent assignments for June graduates are always effective January first.

This type of job rotation has given a far greater payoff than had been originally anticipated.

(a) Really effective placement has been achieved. Asking the Junior two weeks before final assignment where he would most like to work determines where he does his most effective work from his standpoint. Each job rotation permits a supervisor to analyze the Junior's potentialities and estimate where his assets could be best utilized. Weekly conferences and personal counseling are other tools. In six months management knows *where* the Junior belongs, *and he knows too.*

(b) There is no question but that the Junior Engineer after rotation is a much better informed engineer than a similar person who has not rotated. While we have no completely objective yardstick on this, older engineers and supervisors have reached uniform conclusions. Rotation has helped to make a more effective engineer sooner. He

knows where things are in the plant, he knows where people are, he knows division procedures. *He knows what to do to get his job done.*

(c) The Junior Engineer himself knows that he is more effective and that he has been correctly placed. Voluntary quits during the first year of employment have disappeared.

Technical Lectures

Following the decision to inaugurate job rotation, very early in our first year of training we determined that the new Junior Engineers should receive, in addition to other elements of a coordinated development program, weekly technical lectures to be given by the engineers most concerned with the subject matter. A series of lectures mapped out by the Committee represents a kind of survey of the whole field of automation within ARMA's authority to present it. In another sense, the lectures are an overall view of ARMA's technical field of interest. All Juniors receive the same lectures during their first year, whether the Juniors are electrical engineers, mechanical engineers or physicists.

In presenting lectures and the roundtables which follow each series of three or four lectures, our purpose is to attempt a functional description of ARMA equipment —rotating components, transistors and magnetic amplifiers, servomechanisms, gyroscopes, computers and various fire control and navigation systems. We present only such theory as is absolutely necessary to comprehend the simple functioning of the equipment under discussion. The lectures extend over 28 weeks and are given once a week in a 90 minute period. For four or five weeks immediately preceding the technical lectures, the company organization is presented and discussed.

Weekly Conferences

ARMA's weekly conferences (one hour each, in groups of about ten or twelve) are considered the single most important part of the program. They help determine what a young engineer needs, and how we can help him get it.

What a young engineer needs is a function of many variables, the most important of which are considered to center around him and his particular situation at any given time. Because this information centers so intimately about him, in a special sense it must come from him. However, getting this information from the engineer, correctly interpreting it in the light of then existing circumstances and relating it to the job is a complex process.

The Hawthorne experiments revealed a great deal about interviewing that has since been verified and further detailed by many authoritative sources. We know, for instance, that employee comments in themselves do not necessarily give an accurate picture of industrial conditions. The comments always have to be interpreted in the light of the personal situation of the person commenting.

Engineers particularly may mislead an interviewer because he will be prone to treat their remarks as more objective than he should. Because engineers are human beings they have the same difficulty that other human beings experience when they try to specify the source of their problems. However, if the engineer can be encouraged to talk freely, then—like other people—he may be able to reveal to the critical listener the source of his difficulty. This is one very important element in ARMA's research framework for determining needs.

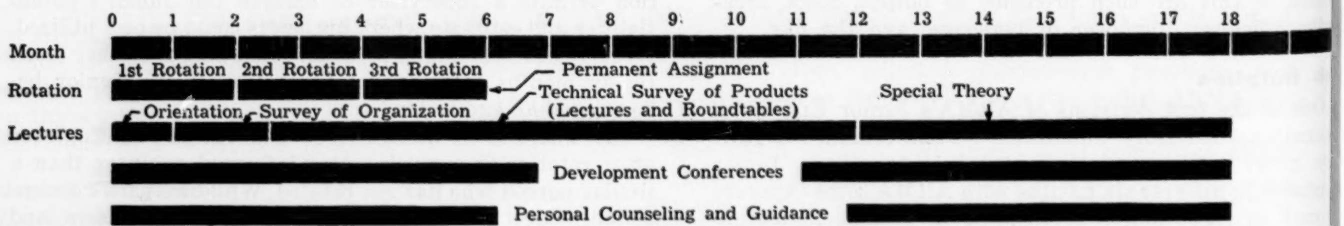
ARMA's new Junior Engineers come from environments that are usually quite different from the one in which they will work as engineers. Some come from one of the branches of the Armed Services. Many, of course, come directly from college. The conferences are designed to encourage the development of a kind of understanding that will result in effective activity and adjustment to these new circumstances. The weekly conferences are not based on textbooks, nor do we even discuss cases. In connection with their training we discuss specific events at ARMA, specific problems and specific goals. The young engineers are provided with a full opportunity to talk over problems with others at the same experience level and to reach solutions acceptable to themselves. They thus help themselves to adjust to new procedures, new situations, specific new work problems and at the same time mutually challenge and stimulate one another with a cross-change of ideas.

Because the productivity of people frequently relates to problems away from the job, personal counseling is also available to the Junior Engineer. The weekly conferences previously described are limited to matters of more or less common interest and are related to events that occur at work. Personal matters are handled privately.

Direction and Participation

One of the concepts so difficult for most engineers (executive or working-level alike) to grasp is in connection with the direction given to any program concerned with the development of personnel. *Where is the responsibility for direction, analysis, decision, action? Whose program is it? What is it supposed to do?* The answer depends on the specific question and the specific company, but analysis and discussion at *all* levels is needed to give perspective and to effectuate the required integration, both corporate-wise and individually.

If the program is accomplishing its work, specific objectives outlined by the planning committee will be met and more detailed problems dug up along the way will be solved. But in addition, the individual engineer will note that he is beginning to achieve a greater harmony between his personal needs and the demands of his occupation. And he will get the feeling more and more that he himself is the active, responsible force in his life.



Really effective placement can be achieved and a better engineer developed faster if both company and individual needs are recognized and planned for.

Research Techniques In

Very High Pressures

Research progress in extremely high pressures is closely related to the development of methods and materials that can withstand the induced stresses. Stationary pressures of 2,500,000 psi can be obtained now and transient pressures to 5,000,000 psi have been reported. Here are some current techniques and their applications.

Ivan Simon
Arthur D. Little, Inc.

The effects of pressure upon the properties of matter are qualitatively well known and are in common use in mechanical applications as well as in chemical processing. However, when the pressures extend beyond the limits of the conventional range, say 100,000 psi, less familiar phenomena are encountered and more spectacular effects are obtained. The latter aspect of the high pressure research made a rather prominent public appearance recently on the occasion of the synthesis of diamond by the research workers at the General Electric Laboratory. Another example of the results from the systematic research in the field of high pressure chemistry is that of polyethylene, first prepared in the laboratories of the Imperial Chemical Industries, Ltd. in 1936 and established now as a material of considerable technical and commercial importance.

However, the principal importance of research in very high pressures is its heuristic value in the fundamental problems of the structure of matter. In the 1 to 10 million psi range which has just begun to be explored, the electronic structure of the atoms is perceptibly affected as manifested, for instance, by their electrical properties. In semiconductors, it is possible to cause the electronic energy levels to approach each other or to overlap,[1] an effect that could hardly be studied otherwise. The further effect of electronic energy level distortion when the pressure is raised by another order of magnitude to the range prevailing in the interior of planets and the stars is still left to speculation.

The effects of high pressures are by and large inverse to those of elevated temperatures. Increase of pressure causes increase of density, favors formation of condensed phases and, by decreasing the intermolecular distances, brings into play forces of interaction that do not operate under ordinary conditions.

In spite of the concerned efforts of several groups of researchers, the amount of systematic data on the properties of matter under very high pressures is still relatively very small. This is largely caused by the inherent difficulties involved in this type of work. Extreme requirements imposed upon the materials in the construction of the apparatus demand extensive experience beyond the range of conventional engineering. Operations are, by necessity, slow because of kinematic limitations such as large masses, high heat capacities or high viscosities.

In general, the experiments are performed inside heavy walled steel containers in very small volumes, thus limiting the size of the experiment. Operation under these restricted conditions requires often a great deal of ingenuity in devising suitable methods for taking the measurement. Preparation of samples and setting up the experiments require meticulous attention to details and a great deal of patience. These are some of the reasons for which research in high pressures is so slow and does not seem to have a wide appeal.

In the following review, we shall limit ourselves to more recent developments, concentrating attention on the techniques of generating pressures beyond 100,000 psi. Instead of attempting an exhaustive description of all existing methods, we shall try to select typical examples that may be of general interest. An excellent review of the subject of high pressure research has been written by P. W. Bridgman in 1946, with 674 references.[2]

Pressures to 200,000 psi

A typical laboratory setup for high pressure work to 200,000 psi is shown schematically in Figure 1. The essential parts—namely, the pressure generator, the pressure gauge and the pressure vessel—are physically separated and individually constructed as more or less standard units. This system is designed to operate with a fluid pressure transmitting medium, usually a light hydrocarbon (isopentane is usable up to 400,000 psi). Pumps, pressure intensifier (1:10 to 1:15 piston area ratio), steel tubing and fittings are all commercially available components. The pressure bomb is usually a simple cylindrical vessel of heat-treated high tensile steel, more or less custom made for the purpose intended.

The pressure gauge may be of a free piston, deadweight type, now available for pressures up to 200,000 psi[3]. The advantage of this type of gauge is that measurements are referred directly to the standards of length, mass and time, with all the corrections theoretically calculable. This makes it suitable for calibration of secondary instruments such as resistance pressure gauges. Of these, the manganin pressure gauge is most widely used, having several practical advantages such as simplicity, ruggedness and continuous indication of pressure. It consists, in principle, of a coil of thin wire, immersed in the pressure transmitting

medium and connected in one arm of a resistance bridge. Manganin, a copper-manganese-nickel alloy, increases its resistance by the effect of hydrostatic pressure at a rate of approximately 1.7 x 10^{-7} ohm/ohm/psi. This effect is very nearly proportional to the pressure over a wide range, the deviation from linearity not exceeding a few per cent to 400,000[4]. Exposure to pressure beyond the rated working range ("seasoning") and temperature cycling between —70° to +100°C are necessary to assure zero stability and reproducibility of the calibration. Several fixed points on the pressure scale may be used for calibration; i.e., the freezing pressure of mercury, 108,660 psi (7640 kg/cm²) at 0°C, triple point of liquid water in coexistence with the two of its solid-phase modifications, ice V and ice VI at +0.16°C and 90,800 psi (6380 kg/cm²), or the polymorphic transformation of solid bismuth at 30°C and 362,000 psi (25,470 kg/cm²).

The design of laboratory size pressure vessels, below 150,000 psi and up to 200-300°C, does not pose any great problem if used with oils or similar organic liquids. Under similar pressures, gases, particularly hydrogen, have a deleterious effect on steels; this is caused by penetration and possible chemical action. Carbon steel and low-alloy (Cr-V, Cr-Ni) steel vessels were reported to fail after use with hydrogen at 45,000 psi or helium at 110,000 psi; with nitrogen, the limit may be as high as 175,000 psi at room temperature. Gas attack is more severe at elevated temperatures. Mercury is likewise to be avoided above 45,000 psi because it causes intercrystalline amalgamation.

The pressure vessel requires always at least one opening of the same or larger diameter than the bore. Openings of 1 to 2 inches in diameter are best obturated by some sort of plug in which the contact pressure on the packing is obtained directly from the internal pressure in the vessel. This can be achieved by making the exposed area of the plug greater than the area upon which the constraints act to maintain the seal[5]. For larger vessels, this type of seal is not practical and various types of ring seals are preferred[6]. For laboratory use, Neoprene O-rings have been successfully used for pressures to 150,000 psi with certain precautions such as reduced groove clearance and doubling of rings.[7]

Windows and electrical leads are quite frequently required to make the measurements inside the experimental chamber. Although flat seating, unpacked windows of orinary soda-lime glass, as developed by Poulter,[8] can be safely used for pressures of the order of 100,000 psi, synthetic sapphire is greatly superior because of its lower compressibility, higher ultimate strength and freedom of anelastic effects. Drickamer[9] has used ¼ to ½ inch-thick sapphire windows for pressures over 200,000 psi. It is important that the windows be cut from the boules so that the plane faces are perpendicular to the C-axis of the crystal. An example of electrical lead using the same principle of sealing by matching plane surfaces (optically polished or finely lapped) is shown in Figure 2.

Pressure Range to 5,000,000 psi

For pressures above 200,000 psi, the typical equipment described thus far becomes useless because the pressure transmitting fluids freeze solid or become too viscous to be pushed through capillary tubing and valves. For pressures up to 300,000 psi, the work may be carried on in an integrated apparatus according to Figure 3. Pressure is generated by forcing a leak-free piston into the cavity of a thick-walled steel cylinder which at the same time serves as the experimental chamber. Maximum pressure obtainable is limited by the tensile strength of the material of the cylinder and by the compressive strength of the piston.

Contrary to the casual reflection, very little can be gained by increasing the wall thickness of the cylinder. An estimate of the size of the effect may be obtained from the theory of elasticity which gives a formula for the tangential stress S_t on the inside of an infinitely long cylindrical vessel of wall ratio r=O.D./I.D.,

$$S_t = P_i \frac{r^2 + 1}{r^2 - 1},$$

where P_i denotes the internal pressure. If the vessel should fail at a pressure at which the internal tangential stress is equal to the yield strength of the steel, the maximum operating pressure would be 80 per cent of yield strength at $r=3$, 92 per cent at $r=5$ and 100 per cent at $r=\infty$. It should be realized that at large stresses a considerable amount of plastic flow may occur and the formulas of theory of elasticity are not applicable.

For further extension of the pressure range to 750,000 psi, and later to 1,500,000 psi, we are indebted to Professor Bridgman[10]. In order to increase the strength of the cylinder, he applied an external radial pressure, which was derived ingeniously from the total thrust on the piston as shown in Figure 4.

In this case, the elastic theory gives a formula for the

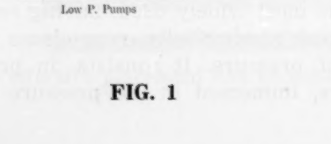


FIG. 1

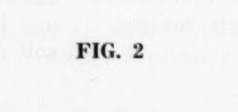


FIG. 2

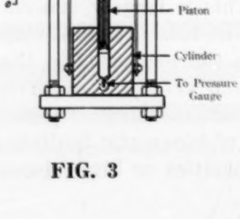


FIG. 3

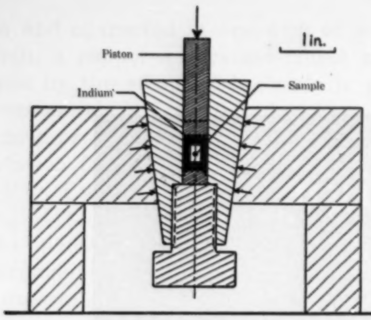


FIG. 4

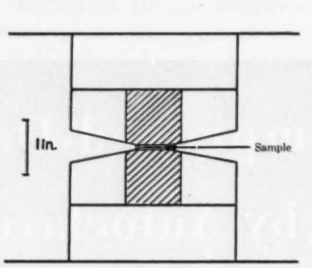


FIG. 5

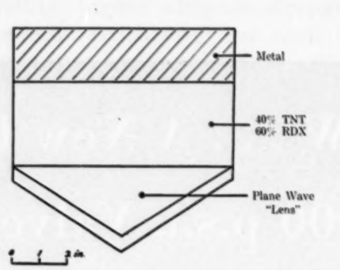


FIG. 6

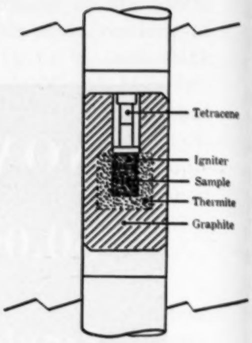


FIG. 7

tangential stress in the bore,

$$S_t = P_i \frac{r^2 + 1}{r^2 - 1} - 2P_o \frac{r^2}{r^2 - 1},$$

where P_o denotes the pressure exerted upon the external surface of the vessel. If P_o is made a certain fraction of P_i, say $P_o = \frac{1}{2} P_i$, the formula reduces to

$$S_t = P_i \frac{1}{r^2 - 1}.$$

Apparently now the maximum internal stress can be reduced to any desired fraction of P_i by increasing the wall ratio. In practice, this advantage cannot be fully exploited because the fixed proportion between P_o and P_i can be maintained only to a limited value of external pressures. Also, with relatively short cylinders, the end-effects may contribute substantially to stress concentration at the points of active support, etc. In addition to providing support for the cylinder, the piston is made of sintered tungsten carbide (Carboloy) which has a considerably higher compressive strength than the best steels. Indium metal which has a sufficiently low shear strength is used in place of the hydraulic fluid.

Above 750,000 psi, this type of apparatus tends to fail by fracture of the cylinder at the bottom of the cone. A more efficient support is obtained by immersing the piston and the cylinder with the experiment in a larger cylinder filled with bismuth and in which a hydrostatic pressure of some 360,000 psi was generated by another piston. Maximum pressures of the order of 1,500,000 psi were obtained. In this cascade scheme, the inside pressure chamber became so small that the extent of experiments that could be performed under these conditions was very limited. In fact, most of the measurements that were made with the apparatus of this type and of the type shown in Figure 4 were of the nature of volumetric changes determined by the displacement of the piston.

Still higher pressures, up to 2,500,000 psi were realized by a drastic departure from the classical techniques, abandoning the piston and cylinder altogether and replacing them with a flat cylindrical space confined between two hard dies or bosses[11] (Figure 5). The dies are made of tungsten carbide shrunk-fit into hardened steel rings, and the sample , in a form of a thin wafer, is compressed in a soft, solid medium such as silver chloride. Lateral extrusion is prevented by a ring made of compressible but nonplastic material; certain kinds of limestone serve well for this purpose. Pressure exerted upon the sample under these conditions may not be ideally hydrostatic because the pressure transmitting medium may sustain some amount of shear stress. Although the kind of experiments that can be made by using this technique is somewhat limited, P. W. Bridgman used it extensively for measurements of electrical conductivity of metals, alloys and semiconductors under high pressures. There is scarcely a pressure gauge that could be used with this apparatus; one way of estimating the pressure is to measure the total thrust and divide by the area of the pill with the sample.

Transient pressures of still higher order of magnitude can be obtained by shock waves produced by high explosives and propogating through the exposed material (Figure 6). The pressure obtained inside of the material of density ρ can be calculated by considering the conservation of mass and momentum as $P = \rho uv$ if u denotes the material velocity produced by the shock wave and v the wave velocity. In recent publications from the Los Alamos Scientific Laboratory, [12, 13] pressures of the order of 5,000,000 psi were reported in metal plates under the impact of shock waves with velocities of 4.5 to 7.5 x 10^5 cm/sec producing particle velocities of 0.46 to 1.6 x 10^5 cm/sec in various metals. Pressures were calculated from the observed particle velocities on the surface and from the empirical equation of the state of the metal providing the relation between u and v. Exploitation of these techniques for actual measurements under transient pressures of microsecond time duration requires considerable refinement of the experimental methods, and certain experiments, such as those requiring long equilibrium times, are not feasible. Also, the use of shaped, high explosive charges ("plane wave lenses") is difficult, expensive and requires proving-ground-type facilities for operation.

High Pressure and Temperature Techniques

Considerable interest in the combined effects of high pressures and temperatures resulted from the geophysical and related problems. Formation of metamorphic minerals, dependence of the velocity of seismic waves upon the conditions prevailing deep under the earth's crust and polymorphic transformation of crystalline solids are a few samples of these problems.

A straightforward design of a high pressure furnace operable to 150,000 psi and 600°C was worked out by Birch and his co-workers[14]. A 1000 watt tubular oven was mounted axially in the bore of a heavy-walled pressure cylinder with electrical connections and thermocouple leads through the plug. The pressure medium was nitrogen pumped up to 15,000 psi and subsequently compressed up

to 150,000 psi by forcing in a piston with a 200-ton hydraulic press.

Since compressed nitrogen (density approximately 1.0 g/cm^3 at 150,000 psi) has a rather high thermal conductivity, the usual porous lagging offers very little advantage except for reducing convection. Consequently, the steel cylinder eventually reaches an equilibrium state at which it dissipates, at its surface, the power supplied to the furnace. The equilibrium temperature distribution was found acceptable from the point of view of the strength of the steel used, even with no other cooling than the circulation of the air on the outside.

It appears that this type of apparatus could be used for considerably higher pressure and temperature ranges, depending only on the dimensional ratio of the furnace and the cylinder. The only limiting factor is the yield strength of the material of the cylinder at the inside diameter as determined by its temperature. With any given heat flow and with a given thermal conductivity of the pressure medium, this temperature can be maintained at any desired level by a suitable choice of the ratio of the inside diameter of the pressure vessel to the external diameter of the oven. Some sort of equipment of this nature might have been used in the diamond synthesis work done in the General Electric Laboratory, although no description of the actual experimental technique has been published yet. The pressures mentioned in the first reports[15] were of the order of 1,500,000 psi and the temperatures in the range of 2750°C. The magnitude of the pressure was such that the experimental chamber must have been supported by external pressure.

High Transients

Previous efforts in this direction were concentrated on achieving high transient temperatures and pressures, in full realization of the difficulties that would be involved in maintaining a steady state with both effects combined at the same time. A large-scale apparatus of this kind, in connection with research on diamond synthesis,[16] was tried during World War II in Germany. Transient pressures of the order of 1,750,000 psi and temperatures up to 3200°C were reported. A slug of electrically-heated graphite was rapidly driven by a piston into the pressure vessel where the final pressure was applied with a 1000-ton hydraulic press. No diamonds were obtained, presumably because of the rapid cooling of the small sample upon compression. A somewhat similar technique was also used by P. W. Bridgman[17] during the initial phases of a diamond synthesis project sponsored jointly by the Carborundum Company, the General Electric Company and the Norton Company during the war. Later, during the course of this work, a more efficient scheme was developed, employing internal heating by means of a thermite charge set off inside the pressure cylinder (Figure 7). Pressures up to 450,000 psi were obtained and temperatures over 2600°C were maintained for short periods of time. No diamonds were produced, but it was established that the rate of graphitization of diamond gradually decreases to zero (at 450,000 psi and 2600°C) and presumably would reverse its direction if higher pressures could be obtained. This corroborated the theoretical estimates for pressures and temperatures necessary for the conversion of graphite, the thermodynamically more stable form of carbon into diamond, the normally less stable modification.

The photograph in Figure 8 shows another small-scale version of an apparatus used for applying transient pressures on samples heated externally to elevated temperatures. The sample is enclosed in a platinum capsule, which is heated by passing a high intensity current through it. The capsule is suspended on its current leads above the orifice of the pressure vessel, while the piston is supported above it by two fracture blocks made of plate glass, adjusted so that they will not break until sufficient pressure is reached. When this happens, the piston shears off the current leads and drives the sample into the cylinder where the final pressure is applied. The apparatus is set up on the platen of a 100-ton hydraulic press with air accumulator, allowing rapid initial travel of the piston. Final pressures up to 250,000 psi, with starting temperatures of 1300°C, were obtained. This apparatus was used in studies involving quenching of melts under high pressures.

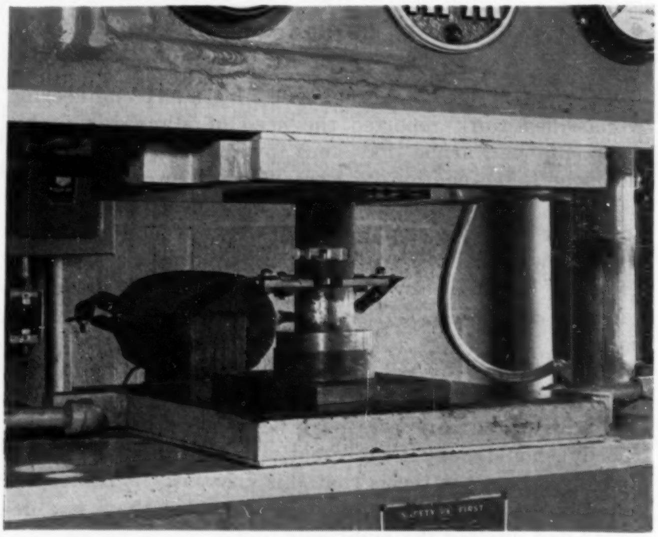


FIG. 8 — Transient pressure setup

Bibliography

1. J. Bardeen, Phys. Rev., *75*, 1777, 1949.
2. P. W. Bridgman, Rev. Mod. Phys., *18*, 1-93, 1946.
3. D. P. Johnson and D. H. Newall, Trans. ASME, *75*, 300, 1953.
4. P. W. Bridgman, Proc. Am. Acad. Arts Sci., *74*, 1, 1940.
5. P. W. Bridgman, Physics of High Pressures, G. Bell and Sons, 1949.
6. B. A. Niemeyer, Trans. ASME, *75*, 369, 1953.
7. A. W. Lawson, Rev. Sci. Instr., *25*, 1136, 1954.
8. T. C. Poulter, Phys. Rev., *35*, 297, 1930.
9. H. G. Drickamer, K. D. Timmerhaus and L. H. Tung, Chem. Eng. Progress, *49*, 503, 1953.
10. P. W. Bridgman, Phys. Rev., *57*, 237 and 342, 1940.
11. P. W. Bridgman, Proc. Am. Acad. Arts and Sci., *81*, 165, 1952.
12. S. Minshall, J. App. Phys., *26*, 463, 1955.
13. J. M. Walsh and R. H. Christian, Phys. Rev., *97*, 1544, 1955.
14. F. Brich and R. R. Law, Geol. Soc. Am. Bull., *46*, 1219 (1935).
15. New York Times, February 16, 1955.
16. P. L. Günther, P. Geselle and W. Rebentisch, Zeits. Allgem. Chemie, *250*, 357, 1943.
17. P. W. Bridgman, J. Chem. Phys., *15*, 92, 1947.

Does the concept "standards" apply to the functions of research and development? Do those in charge of these functions have any interest in "standards" for the entire company? Here's one authority's opinion.

STANDARDS—Platforms of Progress

In Engineering, Development and Research

by John Gaillard
Management Counsel

A few years ago a man engaged in product engineering of classified work reported the need of standards in his group. But he warned that steps toward their introduction should be taken cautiously. Research men, who dominated his group, viewed standardization as a "destroyer of creativity", he wrote. A similar statement was made by a chief engineer who had the creative spirit and ability of a true artist. He held that any restriction of his freedom to select materials and component parts would impair the value of his work.

Such attitudes are not unusual. Through man's progress from the bow and arrow to the guided missile, designers, researchers, and inventors have been proud of their jobs. Nobody should deny their creativity. But neither should anybody accept the thesis that this creativity is destroyed, stifled or hampered by standards—provided these are designed and applied the right way.

Creative Planning

Engineering, Development and Research are closely related functions. They blend into each other like the colors of the spectrum, without clean-cut demarcation lines, yet, with contrasting extremes.

Creative activity, common denominator of the three functions, presupposes visualization of something to be attained—an *initial objective.* This may range all the way from a castle in the air to a practical result which can be attained at once. We may begin by disregarding the question whether the initial objective can be attained and if so, by what means. However, a practical approach calls for analysis of the initial objective to find out what problems are involved, whether we have solutions for them, and what these will cost. The combination of such analysis and review, or *planning,* is the working out of a combination of practical solutions of the component problems of the objective. The solutions not only must be satisfactory for their individual purposes; they must also be in harmony with each other.

Three Basic Types of Problems

In analyzing an initial objective, we may group its component problems under three types, A, B and C, as in Fig. 1. Problems, type A, are those for which we have solutions at hand, such as designs of products that are being manufactured and for which blueprints and specifications are on file. Type B problems are known to be soluble, but their solutions have not yet been worked out. An example is the design of a new product similar to the units of a line of products being manufactured and not differing enough from these to present special difficulties. Since the basic information necessary for the solution of a problem, type B, is available, we know that it can be worked out, and we usually can estimate rather closely the time this will take. No such prediction can be made for the solution of a problem, type C. Here, we have no solution at hand, nor do we know if one can be found. The best we can do is to start working on it.

Three Planning Functions

The three types of problems, A, B and C, are to be solved by the application of functions generally designated as Engineering, Development and Research, respectively.

As shown by Fig. 1, solutions of problems, type A, which result from *Engineering,* may be combined at once into a plan ready to be put into operation. It may be worthwhile to start production on the basis of such an *action plan* (No. 1) even though it meets only part of the requirements of the initial objective. Meanwhile we can start working out solutions of problems, type B, a function designated as *Development*. As an extension of something we have already done, these solutions are new, but since the nature of the problems is familiar to us, no basic experimenting is required. When the solutions have been found, they may be combined, if desired, with the solutions of problems, type A, into an action plan No. 2.

Solutions of problems, type C, usually take more time than do those of problems, type B. They often are basic, such as the development of new materials, methods, components or equipment for which little or no information is available. This expedition into unknown territory comes under the heading *Research.* Before practical solutions are found, suitable for use by Engineering, the process of fact-finding may have to go through two distinct phases: Research, the establishment of fundamental data; and Development, the preparation of a practical working basis for Engineering. Thus, Research may find a relationship between cause and effect, whereupon Development builds

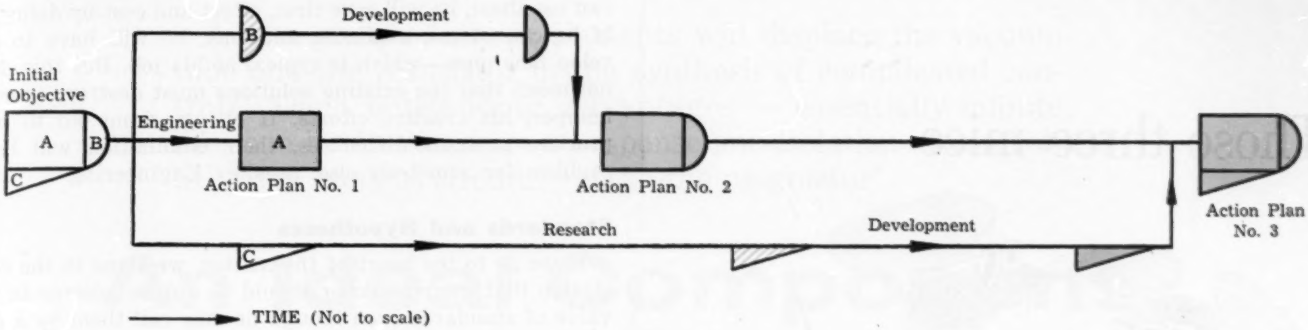


Fig. 1—Planning the attainment of an objective.

a pilot model of a device showing how this relationship works out, and Engineering translates the pilot model into the manufacturing design of a product.

Final solution of all problems, type C, makes it possible to put into operation action plan No. 3 which completely meets the requirements of the initial objective (Fig. 1). The diagram, Fig. 1, is a simplified representation of what is going on every day in countless industrial enterprises. The complete picture would include many more parallel lines symbolizing the solution of problems of different types and the adoption of action plans in various phases of achievement.

Four Activities

Subdivision of the initial objective into problems of types A, B and C may serve also to draw a general distinction between Engineering, Development and Research. Solving known problems by known means is daily routine for Engineering. However, its activities do not stop there. Engineering may also tackle new problems and solve them with known means, or it may apply new solutions to known problems as in Fig. 2. Both of these activities also come under Development and Research. To what function they are assigned depends, among other things, on the nature of the problem, such as its complexity. The fourth activity, Fig. 2, which is concerned with new problems whose solutions still have to be found, is typical for Research.

Overlap of Engineering and Research

As shown in Fig. 2, Engineering and Research each cover three out of four activities resulting from combinations of known or new problems, and known or new solutions. Each of the functions, Engineering and Research, covers one activity that does not come under either of the other two. Development forms an overlap between Engineering and Research, covering two activities which the latter functions have in common.

Evidence of the close relationship between the three functions (Fig. 2) is shown by the way in which they are organized in industrial enterprises. There are executives in charge of Engineering and Development, Engineering and Research, Research and Development, or all three functions combined.

What Value Standards?

If we consider the two activities, Nos. 1 and 4, Fig. 2, we readily understand the differences in attitude toward standardization often taken by men in charge of Engineering and Research, respectively. The "center of gravity" of Engineering normally lies in the application of known solutions and that of Research, in solving new problems. The concept "standard" has been broadly defined as "the solution of a recurrent problem". Engineering has many recurrent problems and hence, an obvious need of standards. The researcher, who deals mostly with new problems that have not yet been solved, may—and often does—question the value of standards to his work.

In this connection the question may be raised how effective would be the researcher's activities if he did *not* have at his disposal standard symbols and definitions; standard units of measurement; standard methods of inspection and testing; and standard means of applying these methods, such as laboratory equipment, instruments and reagents? The researcher may hold that all of these things are merely tools he is using—literally and figuratively speaking—the creative character of his work being far more important. Although granting this to be true, we might draw a parallel here: in manufacturing practice the "creation" of satisfactory product depends largely on the "quality" of the process by which it is made, including tools and equipment, which are accessories to the process.

There is, however, a still more fundamental argument in favor of standards which the researcher might well consider. Even though he may deal almost exclusively with objectives requiring *new* solutions, there are in practice no objectives that consist *entirely* of new problems. Therefore, the researcher is greatly assisted, even in his most creative activities, by having at his disposal numerous solutions of problems that have arisen before; that is, solutions which have become "standard". If the researcher

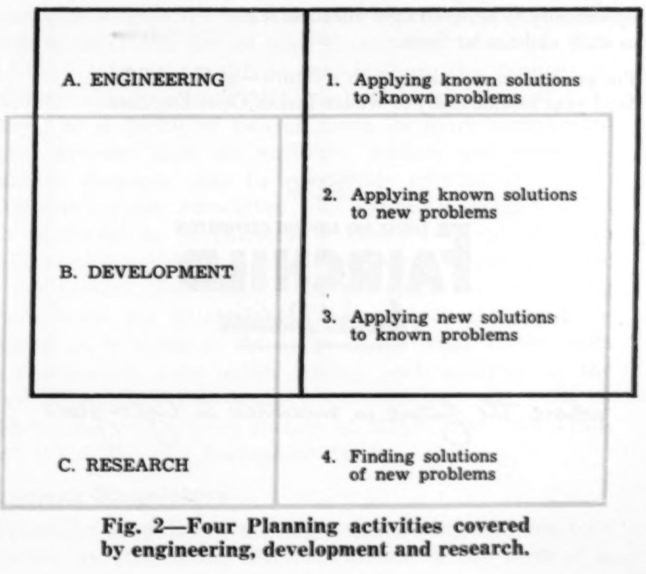


Fig. 2—Four Planning activities covered by engineering, development and research.

can use them, he will save time, effort and cost by doing so. If he cannot use available solutions, he will have to develop new ones—which is typical of his job. But this does not mean that the existing solutions must destroy, or even hamper, his creative efforts. If change from old to new practice presents difficulties, their elimination will be a problem for somebody else, possibly Engineering.

Standards and Hypotheses

If we go to the heart of the matter, we come to the conclusion that the researcher should be a firm believer in the value of standards even though he may call them by a different name. When he follows the approach to new problems that is most characteristic for his work, the scientific method, the researcher proceeds in three major stages. First he formulates an hypothesis based on the best information available to him. Then he designs an experiment to test the hypothesis and find out if it is true or false. Next he carries out the experiment to get the answer. The hypothesis thus serves as a tentative platform of assumption which the researcher tests for reliability as a supporting basis for a new rise to increased knowledge. The researcher will be the first to recognize the need of such platforms. And he will also agree that in principle each platform represents a temporary level of progress which must be shifted as he comes to know more about the subject under consideration.

Industrial standards similarly are temporary platforms in progressive planning and doing. They serve as bases for coordination and assembly of plans designed to meet temporary objectives. Here also, the platforms must be shifted to new levels when planning aims at higher performance or quality as a result of demands of the market, technical progress or both.

Organized Standardization Benefits All

The essential value of standardization as a harmonizer of human efforts toward attainment of a common objective finds increasing recognition. Much is gained if parties interested in a common problem are willing to exchange their views and are ready to compromise for the sake of a solution acceptable to all—be it sometimes with varying degrees of satisfaction.

The idea is not new. About twenty centuries ago, Epictetus made a statement that might well be pinned on the floor of the company's Standards Department, for the attention of all parties concerned—and all *are* concerned with standards, one way or another. The statement reads:

> **"The natural instinct of animated life, to which man is also subject, is self-preservation and self-interest. But men are so constituted that the individual cannot secure his own interest unless he contributes to the common welfare."**

Freely translated into the language of the standardizer, this means that although each department of a company should be left free to set up its own standards for internal activities, it cannot escape responsibility for cooperation in the establishment of *company standards*. This applies to all functional activities, including Engineering, Development and Research. Company standards are indispensable if the enterprise as a whole is to be integrated into a single effectively and smoothly operating unit.

A new group of circuit elements will displace the vacuum tube and the transistor in the synthesis of complicated controls. Their outstanding advantages — essentially infinite life, one-half microsecond response and isolation of controlled from control circuits—make the magnistor*

An Ideal Component for Control Systems

Richard L. Snyder

*Trademark Potter Instrument Co.

The development and use of large scale high speed electronic computers and control systems during the past decade has shown that exceedingly complicated problems, previously insoluble, can be solved and, in many cases, solved very cheaply. It has also led to the application of similar equipment to the control of delicate and complicated processes and machines. Such installations are generally intricate, requiring thousands of vacuum tube amplifiers integrated so intimately that deterioration of a single element shuts down the system.

The number of tubes or transistors used in control systems is determined by the number of functions to be performed, multiplied by two indeterminate factors which are somewhat related to the designer's skill and optimism. The first factor is presented by the purely technical requirement of tubes and transistors; a means must be provided for coupling the output of one element to the input of another element while these terminals are maintained at different D.C. voltages. Frequently, this problem is most easily solved by the use of a second element. The second factor has to do with the necessity of limiting the degree of disaster when failure occurs. If frequent failures are anticipated, the resulting interruption in service must be brief, which implies that its cause must be easily found and eliminated. To speed up the repair process, diagnostic circuits are frequently added. A more elaborate approach to reducing failure troubles is that of building into the system test circuits for finding incipient failures and check circuits to automatically signal the existence of a failure and its location. Such coupling networks and monitoring circuits may increase the equipment requirements relative to the logical requirements by factors of two to five.

The complexity of these systems requires highly skilled maintenance people for finding and replacing defective elements, and because of the specialized nature of the equipment, much of the skill must be developed with the specific machines. The magnitude of investment associated with such installations makes it desirable that it be operated on a continuous "around the clock" schedule requiring a relatively large staff of maintenance personnel. The high initial cost plus the necessity of committing large future expenditures for maintenance makes many potential applications of control mechanisms economically discouraging.

These considerations constituted the reason for initiating the development of Magnistors for amplifiers, gates and logical networks. The choice of magnetic principles was based on three inherent advantages of this approach. First, other magnetic devices such as transformers and magnetic amplifiers are known to have indefinitely long life expectancies. Second, the magnetic link between the electrical circuits provides isolation between controlling and controlled circuits, which is not to be had in any other known single device. Third, an additional degree of freedom in design is available in the choice of the shape and magnetic characteristics of the core which provides a very powerful means of making simple elements of remarkably versatile characteristics.

Long life expectancy is of prime importance in the applications for which Magnistors are intended because it diminishes the frequency of breakdown thereby reducing maintenance problems and the need for checking and diagnostic systems. The resulting reduction in overall equipment requirements decreases the initial cost of the systems and simplifies the maintenance problem.

Independence between the controlled and the controlling circuits in Magnistors permits the cascading of many elements without the use of special coupling networks. This quality in simple amplifiers may reduce the number of auxiliary circuit components, such as condensers and resistors, by a factor of two or more. In more complicated logical devices, such as switches, adders and registers, auxiliary elements may be completely eliminated.

Another quality associated with magnetic devices which also is found in Magnistors is that of adaptability to applications ranging over wide differences in power levels. At the present time Magnistors are made for amplifying signals from the level of thermal noise in the input resistance up to levels of the order of one watt. Other units are designed to gate pulses having peak energies of the order of one hundred watts.

There are two general classes of Magnistors: the Transient types and the Permanent types.

Transient Magnistors

Transient Magnistors are high speed saturable reactors in which an alternating electric current in the form of a

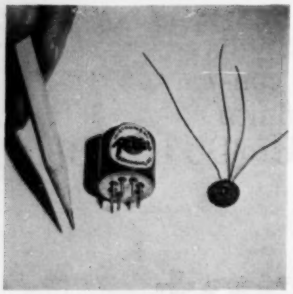


Fig. 1—Magnistor

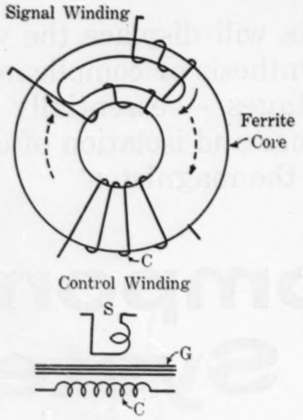


Fig. 2—Transient Magnistor schematic

sine wave carrier or of pulses is passed through what is called the signal winding and is modulated by variations of current passing through what is called the control coil.

In a single transient Magnistor, such as those shown cased and uncased in the photograph in Figure 1 and diagramatically and schematically in Figure 2, the coils are placed as shown on a ring shaped ferro-magnetic core which has a small hole in its rim. The signal winding consists of two coils, one passing through the small hole and the central hole and one passing through the small hole and outside the ring. These coils are connected in series in such a fashion that current through them will cause flux to circulate around the small hole as indicated by the solid arrows rather than around the complete ring. The control coil is wound through the main body of the ring, and current through it causes flux to develop in the direction indicated by the broken arrow. The core material is ferrite, a non-conducting magnetic material having magnetic characteristics like those shown in Figure 3.

In the absence of control current, an alternating voltage will cause current to flow, generating a magnetomotive force indicated by -Ho to Ho, which will develop flux in the core section on which the signal coils are wound that varies in some fashion like that indicated by the small hysterisis loop. When sufficient current is passed through the control coil, the field of the signal coils is biased to some point A where much larger magnetizing forces, $-H_s$ to H_s, resulting from higher currents in the signal winding will not cause sufficient change in flux to develop appreciable signal coil voltages. This means

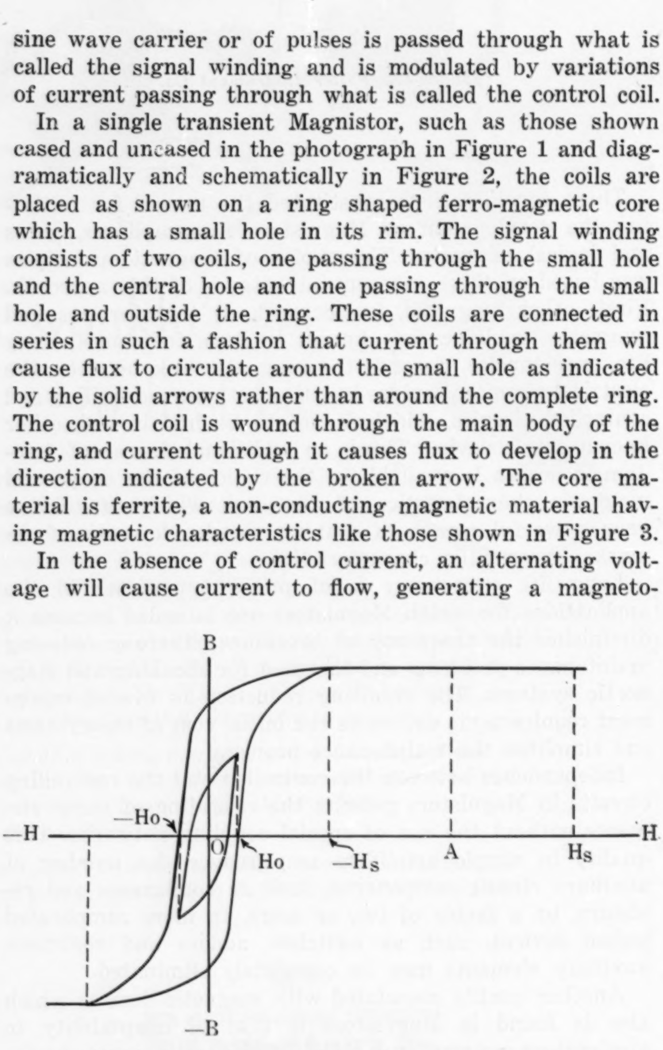


Fig. 3—Magnetic characteristics of core material

that the inductance and, hence, the impedance of the signal winding can be greatly reduced by the passage of current in the control winding and that the current delivered from a generator connected to a load through the signal coil can be controlled by current through the control coil. The energy thus controlled by a given input energy is proportional to the ratio between the frequency of the signal current and that of the control current.

For example, a type ATC2T Magnistor amplifier connected through germanium diodes to a one thousand ohm load and supplied from a 15 megacycle generator as shown in Figure 4 will have the output characteristics shown in Figure 5. When this unit is used to amplify audio signals over a 10 kilocycle band, the power gain between

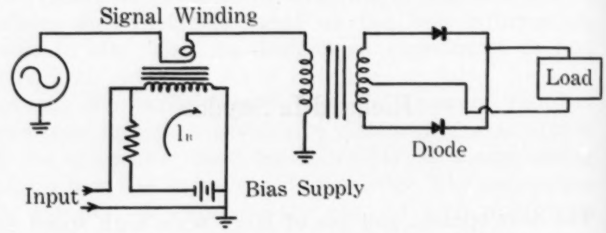


Fig. 4—Magnistor amplifier system

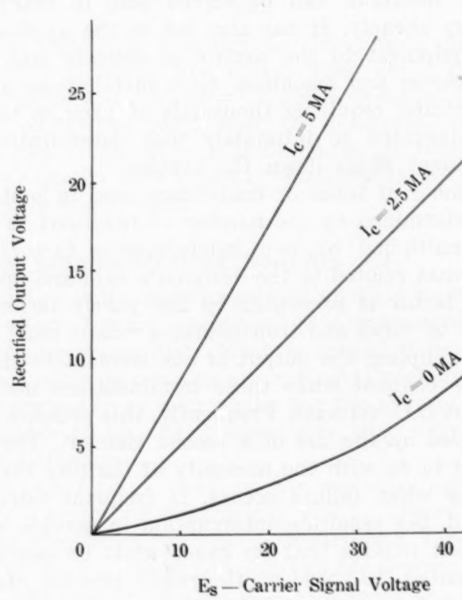


Fig. 5—Type ATC2T Magnistor

the signal impressed on the control coil and that appearing at the load is about 200. In high speed logical or computing circuits in which signals have rise times of the order of a microsecond, the gain of one ATC2T is sufficient for it to drive four others. It should be noted that the polarities of both the input and output signals are immaterial and can be selected to suit other circuit requirements.

Figure 6 shows a somewhat more complicated Magnistor element in which three signal coils are subject to one control coil. In practice, the maximum number of signal coils for one core is twelve in commercially available units. These multiple elements are made for switches used to select magnetic heads on rotating drum memory systems for either recording or reproducing. One switch selecting

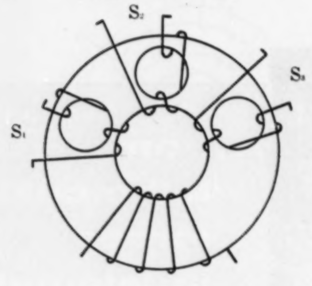


Fig. 6—Multiple circuit Magnistor element

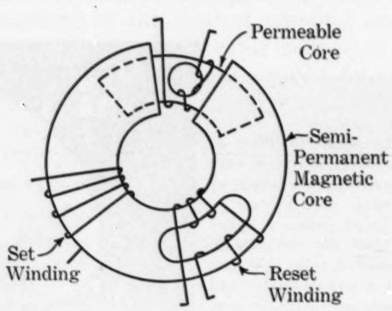


Fig. 8—Permanent Magnistor element

one of 64 heads will accommodate recording signals having peak pulse power of the order of fifty watts and also handle the reproduced signals which travel in the opposite directions (at a different time) having power levels of the order of a micro-watt. No transients develop in the signal circuits during switching, and switching time can be made as short as desired, the time depending on the energy available for switching.

The basic principle of such switches is shown in Figure

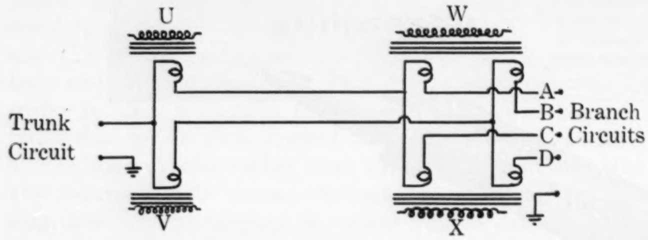


Fig. 7—Simple Magnistor single circuit 4 position switch

7, in which the trunk terminal T can be connected to any one of the four branch terminals A, B, C or D by energizing either control coil U or V and energizing either control coil W or X. If coils U and X are energized, the impedance of the upper signal coil of the first tier becomes low, while the lower one is a high impedance so that a path is established to the first coils of reactors in the second tier and blocked to the second coils of each reactor in the second tier. The lower coils of the second tier have low impedances whereas those in the upper part of the second tier have high impedance. The only complete low impedance path lies between terminals T and C. This principle can also be applied to networks which form binary and decimal adders, logical converters and other intricate specialized switching mechanisms. Usually, only cores and coils are used in these arrays so that there is nothing to deteriorate whether in service or in storage.

Permanent Magnistors

Permanent Magnistors have the property of memory associated with the ability to handle appreciable power.

The signal coil is similar to that of a transient Magnistor but control is effected by means of two coils called the "set" and "reset" coils. A current pulse through the set coil causes the impedance of the signal coil to be low. The condition will persist after the pulse has passed whether power is present in the signal circuit or not. High impedance will be restored to the signal coil if, and only if, a current pulse is passed through the reset coil. The set and reset pulses must be in excess of a prescribed minimum for the full effect but can exceed such minimum by any amount desired which is less than that which would cause destruction by burn out.

Permanent Magnistors are constructed as shown in Figure 8. The signal coil S is wound in the same way as in the transient Magnistors. The set coil C is wound on a core section which has the characteristics of permanent magnet material, and the reset coil is wound through a slot in the permanent magnet core as shown. The reset winding like the signal winding will, when carrying current, cause flux to circulate around the slot so that relative to the main core flux on one side of the slot is in an opposite sense to that on the other side of the slot.

Current through the set coil develops flux in the permanent core and in the signal winding core section. Because of the permanent characteristics of the core, the flux does not disappear after the current ceases to flow, but continues to exist maintaining saturation in the signal winding core. Current through the reset coil develops a similar permanent flux around the slot. However, if the core on either side of the slot has the same cross section, and the same flux density exists in each, the net flux around the main ring must be zero; hence, the core of the signal winding cannot be saturated and the signal coil impedance is high.

Other set and reset characteristics can be obtained by Type GPPI permanent Magnistor, which is designed to control pulses. This is a most useful element because it possesses the characteristics that are conventionally only produced by a flip-flop combined with a cathode follower and a gate. It has the further virtue not available in any other device or system of retaining its conditions through periods of power shut down and even when removed from the system. They are used in registers, controls and other applications requiring permanent bi-stable components.

Other types of Magnistors than those here described are available for amplifiers, gates, registers, switches and binary adders. In addition there are such items as variable auto-transformers for treating both 15 mc power and microsecond pulses in much the same way that low frequency power is handled. Perhaps the general approach discussed here will generate new and useful ideas for simplifying logical operations. Only by this means will such automatic devices as programmed machine tools, small business accounting systems and the myriad of high speed control units used in production operations become so inexpensive and reliable that even the smallest enterprise can afford them. Until such a situation develops, only the largest organizations can afford extensive control systems and even large companies will hesitate in taking such long range and large risks.

Are you delivering what top brass orders?

A little fast pencil work on this R/E quick-check chart will tell you how close you are to top management's dream of a Research Director. Not all of the qualifications set forth by our seven panelists may be practical—but they think they are. They and their fellow executives are spending $4 billion a year on research and development. Here's what they expect you to be doing for their money.

Rx for a Top Notch R/D Boss

Just What Does Top Management Expect of its Research Director?

R/E interviews seven top company executives,

some with big research setups and some with small ones,

and comes up with eighteen solid clues for the successful research head.

Luis J. A. Villalon
Management Affairs Editor

Research and development is American industry's fastest expanding budget. In terms of dollars expended, scientists employed and recognized significance, the rate of expansion can only be described as explosive.

Less than three decades ago, research was barely a poor relation in the management family; today, it has joined management, sales and finance as one of the four pillars of company organization. Since 1941, the cost of research and development performed by industry has climbed five-fold.

This increasing emphasis on research and development has run a parallel course with the phenomenal growth of industry itself. Even the hardest-headed operations man is fully aware that this is no coincidence. Today's support for yesterday's "visionary scientists" comes from the most "practical" quarters in American management.

Research and development has become a deadly serious business to the American company. Accordingly, the company's top executive, responsible for corporate success or failure, must demand more and more of its research and development department and personnel. The R/D men no longer operate in a hidden corner of the company in the relative safety—and frustration—of obscurity. Now the brightest spotlight of management interest is on their day-to-day activities. And they are expected to be efficient as well as creative, profit-conscious as well as Phi Beta Kappa.

The most searching glare is reserved for that scientist turned-manager—Research Director. He is the fortunate soul—willing or unwilling—whom top brass has selected for executive control over this expensive and vital research and development activity. His is not an easy post for the average executive to fill; he must be one of those rare individuals who can graft the art of management onto his scientific training.

Furthermore, the standards by which his competency will be judged are still fluid, only now being set in the majority of companies. To find out just what top management does expect of this hybrid scientist-manager, R/E took the direct course. It asked a simple question, "What do you expect of your Research Director?"—and came up with revealing answers from the heads of a cross-section of American companies, varying in size and operations.

Among those interviewed were Herman Steinkraus of Bridgeport Brass, Dresser Industries' Neil Mallon, Management consultant H. B. Maynard, Penn Salt's William Drake and Ralph C. Persons of Sun Chemical. These big-company bosses were joined in comment by small company heads Arthur Basescu of Bassons' Industries, and Durall Products' Lewis D. Root, Jr.

The sum total of their answers supplies a cross-section of specifications for the ideal Research Director. The sum total of their qualifications may be impossible of achievement, but is certainly something to shoot at. On the following pages, R/E reports their conclusions, in summary and detail. Check up on yourself on the next page—and then listen to solid advice from eight company heads. All of them have to know what makes a Research Director valuable to them—and how to measure his performance.

The Ideal Research Director should:

☐ **"Quickly translate ideas into profits. . ."**
Most companies have to eschew "basic" research for the sake of "applied" research in favor of tangible development of new products and improvement of current products.

☐ **"Keep the company ahead of its competitors. . ."**
Research is increasingly being considered as an active competitive tool, even to anticipating customer requirements.

☐ **"Be a leader of one team and a member of another. . ."**
The Research Director is the "middle man", expected to keep his own scientific staff in hand—and, at the same time, play a full part in management staff work.

☐ **"Select and develop a line of succession. . ."**
It's not enough to be a good man yourself; the boss expects you to select and train younger researchers to take your place in the organization.

☐ **"Combine scientific capabilities with a keen understanding of business. . ."**
Management is looking for that rare fellow who can maintain creative enthusiasm and yet apply the accountant's dispassionate logic to his own operation.

☐ **"Keep his department in line with company policies. . ."**
There's no sense in the Research Department exerting all their energies to improve a lot of products that the company is about to abandon as uneconomic.

☐ **"Advise and counsel management on all technical matters. . ."**
Management looks at the R/D Director like the company doctor, an expert on all things within his realm, whether materials, components, methods or processes.

☐ **"Be a pragmatic educator. . ."**
The R/D Department should stand ready to tackle the little problems raised for individual customers while continuing its cosmic concerns.

☐ **"Call the shots as he sees them. . ."**
Whatever management's attitudes, he can't let them wander off into technical mare's-nests without proper warning.

☐ **"Interpret R/D to management and vice versa. . ."**
Here's the job of communicating management's practical needs to the scientists, and the results of research to management in a manner that will be understood and relied upon by men of business.

☐ **"Know what is going on in competitive companies. . ."**
Sometimes what the other fellow is doing, research-wise, is as important as the activities in your own labs.

☐ **"Guard against over-confidence and over-selling. . ."**
An over-eager research man trying to prove his point can lead the company into premature introduction of new products having serious inherent defects.

☐ **"Fill all posts with qualified personnel. . ."**
Technical knowledge is fine, but the top executive knows from experience that the department is only as strong as the people who are hired—and kept.

☐ **"Get things done in spite of limited resources and frequent interruptions. . ."**
Any executive who served his time in industry knows that there is no campus calm here. He expects results, anyhow.

☐ **"Decide what is practical and what is impractical. . ."**
The neatest trick in the lab is to know when an excursion in a fascinating direction will be worthwhile or just a waste of time.

☐ **"Be practical enough to watch costs with an eye to final product prices. . ."**
It's not enough to design a product and make it work; it's got to be cost-engineered so it will sell.

☐ **"Be something of a dreamer and a visionary. . ."**
In the midst of all this practicality, the Research Director is not allowed to pack his crystal ball in mothballs.

☐ **"Work with a maximum of economy in both manpower and money. . ."**
It's top management's business to be cost-conscious—even in as important an area as Research and Development.

". . . a man of many hats . . ."

BY ARTHUR BASESCU,
President Bassons Industries Corp.
New York City

As reinforced plastics molders, we literally live by our research and development wits.

Working with a ten-year-old material which is just beginning to receive commercial recognition, it is not at all uncommon for us to launch a new product or project for which no precedents—in design, tooling, processing, or finishing—have ever existed. That's why our Research Director must be a man of many hats.

He has to be something of a dreamer and a visionary, else how would he ever devise the techniques which led to plastic boats and automobile bodies, hundreds of aircraft parts, jet pilots' crash helmets, sinks and bathtubs, bulletproof armor, etc. etc.?

But he should be practical enough to watch costs with an eye to end product prices because ours is a new structural material gaining a foothold where traditional metals still dominate.

He must also be a crystal gazer, translating today's experiments into tomorrow's salable products and processes.

On the other hand, we need him as a pragmatic educator. As custom molders to whom customers frequently come with little more than a problem, we offer design and finishing service as well as processing. Though we employ a ratio of one engineer for every 15 workers, we expect everyone in our shop to be technologically alert.

He serves as both our observer and spokesman at professional and trade organizations in which he is active. Not only does he keep abreast of newest developments, but he builds prestige by making public our company's contributions.

Finally, he must be an independent soul. This applies to his dealings with top management, from whom he should nevertheless expect full support. He has to call the shots as he sees them, unpolitic as the situation may sometimes be, because we cannot afford to proceed on anything but proven fact.

A glance at our industry's brief history demonstrates clearly—and frighteningly—the fatal error of cutting corners on research. In the beginning, spurred by urgent military demand for parts and containers made of polyester-fiberglas laminate, many companies plunged willy-nilly into what seemed like an easy and inexpensive process. Just take a sheet of mat, impregnate it with resin, whip up a cheap plaster mold, and you too could turn out aircraft parts, they reasoned.

The balder practitioners of this theory are gone. Nature claimed its own, and the spare garages in which they operated have reverted to family cars and bicycles. Everyone in the industry suffered, however, from the backfire of their exaggerated claims and broken promises.

Only through a research program supported morally as well as physically by top management, can we successfully continue to explore the potential of our new structural material and still give our customers the reliable information which they have every right to demand.

". . . ability to understand and appreciate . . ."

BY RALPH C. PERSONS,
President Sun Chemical Corporation
Long Island City, N.Y.

With a wide diversification of products, Sun Chemical presents a unique challenge to its technical director. Of equal significance is the highly competitive nature of the operations with which almost all of the divisions and subsidiaries are concerned. This, in turn, is reflected in the concerted efforts throughout the corporation toward expanded, speedier, more efficient production. The corporation's management committee, of which our technical director is a member, assists the president in determining the optimum conditions and activities to fulfill the need in this area. It is here that our technical director is called upon to perform one of his most valuable functions in advising the other members of the management committee of these various considerations from a research standpoint.

Generally, our need in a technical director is for a man with the ability and imagination to direct the constant search for new, better products. In addition, he must be concerned with the parallel interest of new, better methods of packing, handling and servicing. Here at Sun Chemical, much of our work among the several divisions often involves custom-built products: inks formulated and mixed for a specific job for a specific client—a building maintenance material for a particular building—a coating for a specific fabric. Here, then, we expect our technical director to be a research-minded man who can function on two parallel levels: the overall, general pursuit of new and better products and the often urgent need for a custom-designed product.

Another requirement is the ability to understand and appreciate the various problems of the several divisions and to coordinate their activities with a maximum of economy in both manpower and money.

Finally, our technical director is called upon to evaluate all of the research activities of all the divisions from both a technical and an economic standpoint and to translate these developments to the management committee and to the president.

In this era of highly competitive industry, progressive technical research represents the lifeline of Sun Chemical Corporation. The lifeline is in good hands—in those of the technical director and in those of the divisions' research directors as well.

". . . an advisor and counsel . . ."

BY HERMAN STEINKRAUS,
President Bridgeport Brass Company Bridgeport, Conn.

Top management should expect that its research director make the most efficient use of the capacities and talents of his department and have organizational ability to fill all posts with qualified personnel. He must direct his efforts, and those of his department, toward the development of new products, the improvement of present products, and he must also serve as an advisor and counsel.

The research director must have a full knowledge of the company's policies, and then maintain his department's activities in harmony with these policies. He must establish a budget of available funds and set up a program of projects for investigation and study with full cooperation and understanding of the rest of the management group.

The research director must have a thorough knowledge of the company's needs. This applies not only to current problems but also to the broader problems facing the company, like a better balanced program and a more complete use of facilities. Customers' requirements constantly change and the research program must be geared to anticipate such changes as far as possible and steer them into channels which will permit his company to compete.

Even in a traditional industry such as copper and brass, improvement in products and processes is continually taking place and a research director must be able to keep his department not only in pace with these changes, but to visualize future developments.

A research director must direct his effort toward maintaining and protecting his company's business and also toward improving its earning position. To accomplish this, his department must assume the responsibility of aiding in the developing of new products, improving present products, and to help devise ways to reduce the costs in current production. This would include methods of production and use of by-products that may have been overlooked.

A research director must also act as advisor and counsel for management on all technical matters and must work in close cooperation with sales, production and engineering. The research director is frequently charged with the responsibility of keeping management informed on the new developments being made in the company's line of products or general field of operations.

A research director and his supervisory aides should keep constantly informed on what other companies in the industry are doing in research. Such knowledge is best gained by establishing and holding contacts with other research people in the field; by regularly attending informative technical meetings and discussions on matters important to research; and by reading the latest reports on research in industry that are made available.

". . . a leader of one team and a member of another . . ."

BY HENRY NEIL MALLON,
President Dresser Industries, Inc. Dallas, Texas.

In our research efforts, great stress is placed upon the necessity of quickly translating ideas into profits. Research in a company such as Dresser must be focused on the practical necessity for developing profitable new products and improving current products rather than for the sake of research itself. In this connection, the Research Directors are especially required to keep the Company a step ahead of its competitors and to anticipate the new product requirements of the Company's customers. The Research Director is also expected to keep abreast of technological developments in other fields which the Company might profitably enter.

Each Research Director is expected to be a leader of one team and a member of another. In leading his own team of research workers he must stimulate creative thinking, inspire confidence, and encourage coordinated effort. The Research Director is expected also to be a member of the top management team and, in cooperation with manufacturing, selling, and finance, assist in planning and carrying out short and long-range programs to improve the Company's profit performance and competitive position.

In short, Dresser Industries looks to the Research Directors of its group of decentralized companies as the source of the continued flow of new products and new ideas upon which the Company's continued success depends. The research groups are given every encouragement to carry out their important and profit-making functions.

". . . we expect a good deal from him! . . ."

BY H. B. MAYNARD,
President Methods Engineering Council Pittsburgh, Pa.

The chief responsibility of our Research Director is to equip our staff of management consultants with the techniques, procedures, and principles which will enable them to aid management with its problems.

The problems faced by management in any period tend

to run in patterns. We expect our Research Director to recognize these patterns. Then we expect him to develop through the research which he directs new or improved techniques for solving the problems involved. Finally he must see that our staff is trained in the correct application of the procedures he has developed.

He must be imaginative, first to be able to see patterns among the variety of problems which are presented to us for solution. He must be able to cut through the "our-work-is-different" aspects of each problem and see the common denominators which underlie them all. Then he must be able to visualize the kind of solution that properly conceived research should yield.

After this he must be able to organize and administer the research project in such a way that it gets done in spite of limited resources and frequent interruptions.

He must exercise sound judgment in deciding what is practical and what is impractical: when an excursion off in a new and interesting direction will yield information of value and when it will result in nothing but a waste of time. He must be able to sense the time to stop collecting data and develop answers from the data at hand.

Working largely with intangibles, as he does, he needs to understand people, for it is people after all that are the problem of every manager.

So all in all we expect a good deal from our Research Director. But not the impossible for we have been well pleased with the results we have been able to get from this concept of research as applied to our activity.

"... an effective channel of communication ..."

BY WILLIAM P. DRAKE, *Executive Vice-President Pennsylvania Salt Manufacturing Company Philadelphia, Pa.*

Top management expects its research director to appreciate the dual nature of his functions: the line responsibility of administering the affairs of his department and the staff responsibility of assisting in the planning of overall Company policy and growth.

Technical competence and some measure of scientific prestige are, of course, prerequisite to the job, but he should combine with his scientific capabilities a keen understanding of business. Thus, he should be subjective and enthusiastic about the ideas and work and accomplishments of his organization and, at the same time, objective and dispassionate in evaluating and presenting the results of research.

We look to our research director to build and maintain a sound, competent and creative research and development organization, and to select and develop a line of succession.

We expect our research director to know the terms in which top management thinks and, in turn, to think for and advise top management about the implications and

ssible effects of new technical developments.

Accordingly we look to our research director to become effective channel of communication between research d development, on the one hand, and top and divisional anagement, on the other, interpreting the viewpoints of ch to the other. We expect him to apportion his time to clude sufficient discussion with management and with the her divisions to permit a thorough understanding of what ey are doing and what they want. He must be able to ansmit this information to his staff in a way that will spire their appreciation of company problems and objec- ves and their cooperation as part of a team striving to- ard a common goal. In the reverse direction, we expect m to communicate the results of research to top manage- ent and to divisional heads in a way that will be under- ood and relied upon by men of business.

Management wants to see prompt and effective use made the results of research, yet research results are almost ver accepted automatically and used as a matter of urse. Management must therefore look to its research di- ctor for that combination of technical and business judg- ent that will guide it in the discriminating and profitable ilization of the product of research and development.

. . keep us informed as any changes in ecifications and purchasing tterns we should make . . ."

BY LOUIS D. ROOT, JR., *President New York Wire Cloth Co. and Durall Products Co. York, Pa.*

Our company, the largest single producer of a staple oduct, is the kind that often tends to neglect research. e don't for two reasons—because it was research result- g in the invention of the basic processes used in the anufacture of wire screening many years ago that put in this dominant position today, and because we are rrently broadening our activities into new and different oducts just as fast as we are able to, either internally or rough the purchase of other companies.

Under these circumstances, and with a small staff, we e forced to expect a great deal of our research director. (1) We expect him to be able to take rough ideas for w products and prove them practical or impractical to anufacture for marketing, at a price.

(2) We expect him to be able to examine and evaluate wide variety of products from other companies that we e considering buying as a part of our expansion program.

(3) We expect him and his organization to come up with share of creative ideas that will aid our expansion. To do all this he must keep up with all the new develop- nts in ours and related fields. After all, he's also our one xpert" on new products, materials and processes. It is his to keep us informed as to any changes in specifications purchasing patterns we should make.

Book Reviews

Turboblowers

BY A. J. STEPANOFF

Reviewed by Israel Katz,
Associate Professor Thermal Engineering, Cornell University

It would seem that because so many blowers and compressors have been built in a variety of types and sizes, and since the turbocompressor has been brought to such a high state of development in recent years, there should be little need for a new book on the theory and practice of gas vapor pumping turbomachinery.

However, those engineers who work with turboblowers and others who on occasion deal with them, realize the critical need for a definitive book on the subject. Moreover, many engineers who have designed and tested successful blowers and compressors have long recognized the existence of a gap between the experimental results and the related theoretical computations. In general, it has been the custom to rationalize the discrepancies as practical deviations from the ideal. Many interesting, if not ingenious, theories have been devised to explain the differences. While much of the gap has been bridged, the explanations have not yet dispelled the feeling that there is more to this matter than meets the eye.

Dr. Stepanoff's new book was written with a view not only to provide the student and practicing engineer with an authoritative text and reference book on the theory, design principles, performance criteria and application principles of turboblowers and compressors, but also to eliminate some of the uncertainty associated with them.

Much of the uncertainty associated with turboblower theory is eliminated by Dr. Stepanoff's use of a well-known but little applied thermodynamic approach, which arises from his conviction that: "Several important deductions known and confirmed by observation cannot be arrived at by the conventional use of internal energy and enthalpy functions alone, whereas they do follow simply and logically with the aid of available energy functions."

The reader also will benefit from Dr. Stepanoff's abandonment of classic airfoil theory that now is used widely to explain the action of axial compressors, although the theory is introduced to acquaint the reader with the terminology and show its limitations. He has dispersed the fog laid down by those souls who feel compelled to describe all technical things, however simple, in difficult terms. In the preface Dr. Stepanoff says: "The theoretical treatment of the axial flow impeller is based on the actual *fluid deflection angles* rather than airfoil lift coefficients. In this method axial flow machines appear as an extreme type in a continuous row of hydraulic types. The forced vortex pattern of flow through the axial flow stage is a logical development in this design procedure. In high-pressure multistage axial flow compressor design, the trend is definitely away from the airfoil theory and from the free vortex pattern of flow."

The first two chapters which cover pertinent concepts and definitions, set the stage for what follows and do it without giving a short course in engineering. To benefit from use of this book the reader should have a sound understanding of engineering thermodynamics and fluid mechanics.

The following four chapters are devoted in effect to the theory, design criteria, general characteristics and performance of centrifugal machines for incompressible fluids. They demonstrate how the transfer of energy between a rotor and a fluid is accomplished as well as why the design of the machine and the properties of the fluid pumped affect the qualitative characteristics of the pumping processes.

The thermodynamics and mechanics of compressible fluids then are treated from a viewpoint of their application to turbomachinery. Here, the objectives are to develop an understanding of the several capacity and efficiency criteria and an appreciation for the influential factors and effects associated with the practical deviations from the ideal.

This basic material is followed by discussions bearing upon the theory and design principles related to the fixed parts of blowers and compressors, factors affecting leakage, viscous friction at the rotor, mechanical losses and axial forces. The topics of cooled compression, intercooling and injection cooling also are covered here to show how the specific work of compression and the size of equipment to pump at given rates may be reduced by cooling.

Three separate chapters are devoted to the theory, design and application of centrifugal fans; single stage axial fans and blowers; and high-pressure multistage axial flow compressors. This material precedes a separate chapter dealing with special problems in weight and capacity control, the design and the application of blowers and compressors.

The book closes with an intriguing clarification of what seems to be the most difficult problem confronting the designer: the geometric layout of mixed flow impellers. Here, Dr. Stepanoff discusses the pertinent geometrical relationships, shows why plain vane faults may lead to inordinate shock losses, explains the successive approximation helpful in the design of mixed flow impellers and describes "the method of error triangles" for use in design.

Probably the most noteworthy quality of the book is its clear and concise presentation of difficult concepts, thereby favoring the imaginative visualization of physical phenomena that is so essential to a reader's understanding of pertinent principles and their application to engineering practice. The explanation for this important quality, of course, is that much of the material presented is drawn from the author's personal technical experiences with turbomachinery and that the author has the unusual ability to discuss involved matters witout being pretentious.

The book contains many important statements touching upon the fine points of turboblower design. It contains many examples, is well illustrated and gives numerous references in the technical literature. The end result is readable, highly original and informative.

It is the reviewer's considered opinion that this book is a notable contribution and, like Dr. Stepanoff's other excellent work "Centrifugal and Axial Flow Pumps", it will be recognized as an authoritative source of information on turboblowers.

John Wiley and Sons, Inc., New York, N.Y., 377 pages, $8.00.

Transistors: Theory and Application

BY A. COBLENZ AND H. L. OWENS

Reviewed by Robert L. Snyder, Sylvania Electric Products, Inc., Woburn, Mass.

The transistor industry is going through the seemingly long phase of component and circuit development wherein much effort is expended and apparently few finished products come into public view. Although the initial glamour has worn off and the "hasty predictions" have been tempered by realistic accomplishments—and setbacks—nonetheless a pattern for success is emerging.

Take a look at the record! Laboratory research has brought out many new types thought almost impossible or impractical just a few years ago. Transistors with responses better than 50MC have been pro-

duced by special techniques. Grown silicon and rate grown germanium junction types are now on the market. Work has advanced on inter-metallic compounds other than germanium or silicon which should remove eventually many of the current restrictions peculiar to these two elements. High powered transistors have been available for many months. Fully transistorized portable radios have been on sale since the first of the year. Completely transistorized computers, TV sets, oscilloscopes and other devices have been built and proven practical. Several companies have announced improvements in manufacturing methods which should tend to bring the laboratory prices of transistors more in line with comparable vacuum tube types. One concern recently developed an automatic "transistor assembler" that could serve as a prototype for complete automation of transistor production.

Indeed, one can see the time approaching when higher level thinking in practically all phases of the electronic industry will be inexorably tied up with semiconductors —and particularly transistors.

One phase of this growing field which must be brought into sharper focus is the training of personnel at the graduate and technical level Those in top management positions should encourage a wider dissemination of transistor know-how in the form of training programs, lectures, books and subsidization of courses. "Transistors: Theory and Application" thus makes a timely appearance on the scene. It is the type of textbook that research, design and development heads can and should recommend to electronic engineers who wish to be indoctrinated in the "fine art" of semiconductors preparatory to going on to more advanced topics; or to the designer who is actively engaged in some aspect of transistor production or application; or perhaps to those who just desire to obtain a reading knowledge of this fascinating device. This last category might include the busy executive who desires to obtain a talking knowledge of transistors without having to wade through long formulae and heavy mathematical treatment. The ground covered is widespread albeit concise, with a short preliminary section at the beginning of each chapter and a summary of the salient points at the end. The book is thoroughly enjoyable and is heartily recommended by this reviewer as an introductory text.

Aside from a short historical chapter on this twentieth century marvel, the book begins as expected with a development of the physics of transistors. The presentation is very good, particularly in the step-to-step tie in with experiments, theories and laws promulgated in the last 60-70 years. The importance of the concept of "holes" is brought out. In fact, the whole idea of having to learn new concepts which are decidedly different from those in general practice is stressed.

Chapters on the description, merits and limitations of point contact and junction transistors are given next. In this section as well as throughout the book, emphasis is placed on a brief presentation of a variety of subtopics rather than a complete developmental analysis. Although this leaves much to be desired, one begins to see a well-rounded picture of the peculiarities and advantages of both types.

The authors then present a standard discussion of the "Black Box", and grounded bases, emitter and collector configurations. Typical values of the various parameters are given, and comparisons between point and junction types are made. Once again, the treatment is sparse, but a wealth of summarized information is packed into a compact section.

Unfortunately, the chapters concerning applications are limited to switching circuits (point contacts) and cascading transistors (junctions). Thus, the design of most of the common circuits, particularly in the high frequency realm, is left to other texts. However, the commentary and examples are excellent as far as they go.

The last three chapters take up manufacturing processes, silicon and special topics. These should interest both researchers and management not directly associated with semiconductor production methods. That the whole process is quite an achievement in control is brought to the fore. The reader begins to understand the complexity of some of the problems and appreciate the results to date.

One of the least publicized reasons for the lag in transistor usage is the lack of trained engineers, technicians and scope of transistor "know-how". Therefore this book is welcome, for despite its limitations, it should serve as a useful training manual.

McGraw-Hill Book Company, Inc., New York, N. Y. 313 pages. $6.00.

The Colloid Chemistry of Silica and Silicates

BY RALPH K. ILER

Reviewed by David Bandel, Senior Chemist A.M.F. Chemical Research and Development

In general, books written on silicon chemistry tend to be highly specialized and delve rather exhaustively into limited phases of this multi-faceted field of chemistry. This book is rather broad in its coverage of silica chemistry. Colloidal silica chemistry treated here includes the surface chemistry of silica solids, the organic esters of silicic and polysilicic acids in addition to soluble silicates. The term colloidal is used in its broadest sense.

The initial chapters deal with the solubility of silica in water and a brief discussion of the soluble silicates. Subsequent chapters covering the chemistry of silicic acid and collodial silica are quite detailed and of considerable technological interest. In particular, the availability of colloidal silica in high solids aqueous sols has led to its use in such diverse products as refractory casting molds, floor waxes, polymer modifiers and textile delustering and soil resistant agents. The chapters on the methods of preparation and surface chemistry of silica gels and powders will be of interest to those in the field of cracking catalysts, adsorption and mineral pigments and fillers.

Other chapters discuss the organic esters of silicic and polysilicic acids (not the silicones) and selected silicate minerals having unusual surface or colloidal properties.

The final chapter contains a rather interesting discussion of the role and utilization of silica by living organisms.

This book is not intended to be a monograph. Although the literature is not searched exhaustively, there are an adequate number of references that will enable the research chemist to obtain more detailed information on any phase of the field that strikes his interest. The subject matter, presented in a direct, clear and concise manner, contains a great deal of useful information.

The book will be of interest to industrial chemists because its theoretical treatment is of the type valuable for building a working theoretical basis for industrial research and development.

Cornell University Press, Ithaca, N.Y., 324 pages, $5.50.

Development of the Guided Missile

BY K. W. GATLAND, F.R.A.S.

Reviewed by Arthur Sommer Arma Division, American Bosch Arma Corporation

Ten years ago over 1000 V-2 guided missiles fell on England. The sole defense against them then was to destroy their launching sites. In the decade that has passed since World War II, the development of pilotless aircraft has become a perfected reality. Is there now an effective defense against a guided missile with an atomic warhead plunging out of the sky at 4000 mph? Mr. Gatland reviews the development of the guided missile and thinks not.

Against the backdrop of the British Isles with its high density industry and population and with Soviet bases only 600 miles away, the author is quite naturally perturbed about the defensive problems raised by the guided missile. But the present vulnerability of the British Isles is nothing less than a preview of our own situation when the intercontinental missile becomes a reality. The indication is that there is not very much time left.

The text does not pretend to cover a specific phase of the guided missile develop-

ment. Rather, it presents to a technical though not necessarily specialized reader, the broad aspects of missile development. The material contained in the text is nothing startlingly new since in general it is assembled from previously published reports. But the continuity afforded by this assemblage is a real service. Particularly, the tabulation of the characteristics of over 130 missiles is extremely valuable to the interested observer struggling to interpret the wealth of articles currently being published on missiles.

In addition to reviewing the pioneering developments of the Germans and the continuing developments of the United States since World War II, Mr. Gatland takes a long hard look at the probability of the state of the art in Russia. He covers air-to-air, air-to-surface, surface-to-air and surface-to-surface, missiles. The high altitude bomber, the long-range missile and even the antipodal bomber are reviewed. For the more adventurous souls, the space-satellite rocket and the interplanetary rocket problems are discussed.

The problems of propulsion and test facilities are covered with some thoroughness. Aerodynamic considerations are generally presented, although the re-entry problems associated with extremely high altitude missiles could be more detailed for general interest. The guidance problems for missiles are handled somewhat sketchily although security restrictions probably necessitated elimination of details. While it is true that nuclear weapons with their almost incomprehensible destruction radius mitigate the guidance problem, it would appear that the jamming of the guidance system might be an effective defense. A more detailed discussion of the advantages and limitations of the various guidance means would have contributed to an extrapolation of future progress.

Recommended as excellent background material.

Philosophical Library, New York, 292 pages, second edition, $4.75.

Management of Expanding Enterprises

BY WILLIAM H. NEWMAN AND JAMES P. LOGAN

Reviewed by John W. Cook
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This book is the result of round table discussions on management problems associated with expansion of industrial enterprises. The title does not completely describe the study, for many problems are posed which do not have answers. This reflects the difficulty in quantitative measurements of managerial tasks and the individual character of problem solutions depending upon the particular organization and its previous history. Six classes of problems are considered: the effect of company size, basic principles of decentralization, the role of the chief executive, the analysis of operational results, the connection between size and morale and problems unique to the transition phase. Additional discussion is given to decentralization problems in government and other highly integrated establishments. An appendix is added containing many questions pertinent to areas requiring further research.

A difficult class of problems is dealt with. The reader will find many instances resembling problematic situations in his own organization, and he will be able to compare some typical solutions with those he has dealt with first hand. Heavy emphasis is placed on the reasons for decentralization, chiefly concerned with the inability of top management to carry the administrative load as the company grows. The modern consumer market which demands diverse technological capabilities coordinated in the same business enterprise with a consequent need for research, specific production talent and decentralized sales and marketing facilities are responsible for most decentralization programs. As the diversity of products increases, top management finds it more difficult to maintain first hand contact with the various phases of the enterprise and begins to develop subordinate managerial posts, requiring different techniques for control and company strategy. These problems are discussed in detail, but no specific conclusions are given. Perhaps it is significant that heavy emphasis is placed on the use of policy decisions in controlling a decentralized organization, and heavy stress laid on the relaxation of top management in detailed procedures, relegating operating decisions to the lower echelon.

The difficulties in specifying and restricting the job of the chief executive are considered. It is emphasized that the chief executive should occupy himself with long range plans and with an objective evaluation of men and their capabilities, not interfering in procedural matters, however. Adherence to the chain of command to maintain sound organizational structure is stressed. Basically, the leadership quality of top management and the need for a sensitivity in selecting managerial personnel are emphasized. It is pointed out that the latter problem must be handled on an intuitive and personal basis due to the lack of more quantitative methods.

The book is extremely readable and will be valuable to many managers in contemporary organizations. If it does no more than indicate the widespread character of low echelon management problems, it will have served its purpose admirably.

Columbia University Press, New York, 125 pages, $2.75.

Research Reports

Reports in this section may be obtained directly from the Office of Technical Services, U.S. Dept. of Commerce, Washington, D. C., unless another source is stated.

Survey of Synthetic Lubricant Sources

The Air Force's two year research program on the actual and potential supply of materials for synthetic lubricants is now available in final report form.

This study, done by the Standard Oil Development Company for Wright Air Development Center, has been approached in two ways: a survey of the potential availability of raw materials from which ester-type lubricants can be made; and an evaluation of many types of esters to determine their suitability as lubricants for high-power aircraft engines.

The first part of this program included a survey of data from various literature sources on over 800 compounds, chiefly esters. Most available of the esters studied were adipic acids—chain-type dibasic acids which can be derived from petroleum—and Oxo alcohols. Another promising source of synthetic oil appeared in polypropylene glycols. This literature survey provides a useful compendium of available information on ester-type lubricants.

In the second phase of this study many types of esters were evaluated for the fundamental properties which make them desirable as lubricants for aviation equipment. These include good viscosity-temperature and viscosity-volatility relationships; low melting and pour points; stability toward oxidation, hydrolysis, and heat; and good lubrication characteristics. **Synthetic Lubricants,** *PB 111565, 168 pages with charts and tables; $4.25.*

Stainless Sulfonate Lubricants

Purified sulfonates may now be used in lubricating oils with no danger of stain damage to metals. Experience and the investigations of numerous authorities have indicated that preservative compounds containing the cheap and abundant sulfonate inhibitors frequently leave stains which seriously reduce the corrosion resistance of metals, particularly precision ground parts.

Through a series of experiments described in this report, the Rock Island Arsenal Laboratory, Army Ordnance Corps, traced the trouble to two constituents of the commercial inhibitors—water soluble sulfonates and inorganic salts. The extraction of water or oil-soluble sulfonates presents particular difficulties, however, since they cannot be removed with the usual organic solvents. A special process was devised in which the sulfonates were "de-oiled" and then purified by extracting the solution with toluene. Tests in humidity and fog cabinets indicated that the extraction procedure materially reduced staining and improved the protective ability of the inhibitors.

An Investigation to Determine the Effect of Purification of Commercial Sulfonates on Their Corrosion-Stain Property, *PB 111572, 20 pages; $.50.*

Citric Acid Cuts Evaporator Scale

Scale in sea water evaporators can be controlled and production maintained indefinitely by frequent descaling with citric acid, according to a report of the Army Engineers. Many island military bases and commercially-important areas such as Kuwait and Curacao depend wholly or in part on distilled sea water for their water supply; therefore, the Corps of Engineers has conducted extensive research in cooperation with other government and private research agencies to discover the most productive and economical method of sea water distillation.

Their experiments show that when low cost fuel is available, thermocompression distillation, based on the principle of the recycling of heat, is much more efficient and economical than the conventional triple effect still. The major obstacle to thermocompression operation is the formation of briny scale on evaporator tube surfaces which can limit operational periods to as low as 200 hours and double the cost of distillation.

Results of tests of various methods of scale control conducted since 1947 are discussed in this report as well as comparative costs. Immediate descaling with citric acid in hot brine was found to return a machine to operation within an hour. The use of citric acid increased production 20-fold with runs up to 10,000 hours without descaling.

Water Treatment, Prevention of Scale in Sea Water Distillation, *PB 111569, 130 pages; $3.25.*

Plastics With Improved Properties At Low Temperatures

Unexpected strength and toughness at low temperatures have been discovered in certain plastics which at room temperature give only mediocre performance. The Ordnance Corps conducted this research because of the wide use of plastics in ordnance items and the need for a uniform basis for quantitative comparisons between a large number of materials. Laminated thermosetting materials gave outstanding low-temperature performance; glass fabric laminates proved the strongest. All laminates showed increase in tensile strength to temperatures around —40°F., with slight reductions in strength, caused by embrittlement, as the temperature approached —65°F.

This report provides valuable design data and information on the low-temperature properties of 56 different rigid plastics representing all commercially available types. These include a wide variety of laminated, molded, and cast thermosetting materials as well as cellulose, polystyrene and polymethyl thermoplastics. Properties tested at temperatures ranging from +77° to —65°F. included tensile modulus of elasticity, proportional limits, elongation at break, ultimate tensile strength, Izod impact strength and work-to-produce failure.

Mechanical Properties of Rigid Plastics at Low Temperatures, *PB 111579 143 pages with charts; $3.75.*

Sonic Treatment and Testing of Wood

A study of sonic and ultrasonic vibrations in the testing and water-repellent treatment of refractory woods was conducted in an attempt to develop an economical and effective method of treating them to prevent shrinking and swelling and to investigate the use of sonic vibrations in testing the strength of wood beams and timbers.

Comparative tests of ultrasonic, dip and pressure treatments, using commercial water-repellents and a water-glycol solution, indicated that ultrasonic vibrations of 440 kc and above improved absorption and anti-swell efficiency of hard-to-treat woods. While pressure treatment gave generally better results under test conditions, the ultrasonic vibration treatment shows some improvement over the dip method and gives promise of still better results when techniques of application are fully developed.

The sonic testing of strength properties of wood appears to offer several commercial advantages. By this method of measuring resonant frequencies, weakening defects in wood beams and construction items can be discovered without test damage to the

wood. Standing timber may also be tested to determine its soundness.

Application of Ultrasonic and Sonic Vibrations for Improvement and Testing of Wood (Final Report), *PB 111556, 59 pages with photographs and diagrams, $1.50.*

Military Electronics Design Manual

A manual for designers of military equipment on the application of electron tubes has been produced by the Air Force and is now available to industry. Prepared by the Electronics Components Laboratory of Wright Air Development Center in January 1955, this report presents 100 pages of tube information from the point of view of the electronic design engineer.

In the first section tube properties are discussed according to ratings, characteristics essential in circuit operation and properties detrimental to circuit operation. The second takes up tube properties in circuit design including a check list for the use of the circuit designer to insure coverage of all important design factors. The third contains numerical data and special design considerations for specific tube types. The concepts of specification control, operation within ratings and tolerance characteristics are emphasized throughout the report.

Techniques for Application of Electron Tubes in Military Equipment, *100 pages, PB 111644, $2.50.*

Temperature and Pressure Refrigerant Data

Technical information which will give the refrigeration industry improved basic data for greatly extended ranges of refrigerant pressure and temperature resulted from several years' research for new and more accurate thermodynamic data of "Freon-12" dichlorodifluoromethane.

Completion of the project, conducted jointly by the Engineering Research Institute of the University of Michigan and the Du Pont Company's Jackson and "Kinetic" laboratories at Deepwater Point, N.J., was disclosed to the American Society of Refrigerating Engineers at their 42nd semi-annual meeting by Du Pont's R. C. McHarness. He delivered a report of work done jointly by Dr. B. J. Eiseman of Du Pont's "Kinetic" Chemical Division, Professor J. J. Martin of the University of Michigan and himself.

In the research study a total of 150,000 values were calculated. Of these, 40,000 are included in three saturation tables and 255 superheat tables, covering a temperature range of —150°F to +515°F and pressures from 0.14 to 588 pounds per square inch absolute. That range, with measurements accurate to one per cent or better, "should meet all possible needs of the refrigeration and other industries" for many years, McHarness said. The origi 1931 tables on "Freon-12" covered on the —40°F to 140°F range.

In several of the 14 charts the range i extended to 700°F and 5000 pounds pe square inch absolute. Extent and signif cance of the research is pointed up, th authors explained, by the fact that th calculations needed for the new data woul have required the full-time work of on man for 100 years. Latest "electroni brain" computers used in the study di the actual calculations in about 30 hour

Greatest usefulness of the new da aside from increased accuracy and co sistency, will be in sharply decreasing th amount of interpolation required of e gineers using existing technical data o "Freon-12" dichlorodifluoromethane t arrive at the operating temperatures an pressures in refrigeration equipme While the new data require no majo change in current design conditions, the will, by extending the range of previous available data, greatly simplify engineerin and design work as refrigeration equip ment goes toward higher and higher com pressor pressures and temperatures.

Included in the new data, which D Pont's "Kinetic" Chemicals Division is pub lishing in manual form as a refrigeratio industry service, are ten pressure-enthalp charts, including broad-range, a single sheet refrigeration-range chart, and eigh large-scale diagrams covering the refrigera tion range; a single broad-range entrop enthalpy diagram, and three graphs o specific heat data, broken down by consta pressure, constant volume and the ratio o pressure to volume.

Three saturation tables present data i the form of even temperature values, eve absolute pressure values, and even gaug pressure values, while 255 individual tabl are included to provide superheat dat Among the latter, 129 tables are devote to constant pressure for even values o saturation pressures, while the remainde deal with constant pressure for even valu of saturation temperatures.

Greater accuracy and less interpolatio are achieved with the new data, the a thors pointed out, because of the greate number of values and narrower tempera ture and pressure intervals. Previo charts were based on double the new mea urements.

The new computations represent, D Pont said, the first major revision of the modynamic data on its "Freon-12" d chlorodifluoromethane in 24 years. Th "Freon" fluorinated hydrocarbons, firs marketed in 1931, are used as the col making agents in practically all home r frigeration and air-conditioning equipme today, and in an increasing share of in dustrial and commercial cooling and ic making equipment.

"Freon-12" *report available from E. Du Pont De Nemours and Compa Wilmington, Delaware.*